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Leading Learners to Level Up in a High School Mathematics Classroom

Jennifer Carnes Wilson
University of Mississippi

LEADING LEARNERS TO LEVEL UP IN A HIGH SCHOOL MATHEMATICS CLASSROOM

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JENNIFER C. WILSON

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ABSTRACT

How often are teachers surprised to find out at the end of a learning episode that students have not actually learned? The first Mathematics Teaching Practice from NCTM's *Principles to Actions* asserts that "effective teaching of mathematics establishes clear goals for the mathematics that students are learning, situates goals within learning progressions, and uses the goals to guide instructional decisions" (NCTM, 2014, p. 10). Unfortunately, many teachers struggle to establish clear goals to focus learning, and many students struggle to meet those goals.

This research study considered how well students predict success on learning targets for an upcoming test when they are given the chance to rate themselves before they take the test and whether treatments such as worked examples and metacognitive strategies move predicted levels closer to actual performance on the test. Additionally, the research study considered whether there is a difference in the ability to predict success level between engineering and non-engineering students since engineering students use learning targets in both their math and engineering classes. Through questions on a student Google form and for a teacher interview, the researcher sought to determine student and teacher perceptions around using learning targets to inform student progress in learning.

This research study sought to determine whether using learning targets, worked examples, and metacognitive strategies can ensure that students not only know what is

going to be on the test, but also are better able to predict how they are going to do on the test.

DEDICATION

This work is dedicated to all of the learners I have had the privilege of learning alongside, students and teachers and friends, who have made me think about what is important to learn and how we will know when we have learned it.

ACKNOWLEDGEMENTS

This work was inspired by my friend and teacher, Jill Gough, who has been my lead book recommender and thought provoker. I am grateful to many colleagues and students whose questions have taught me not just to wonder why but also figure out why. Thank you to Dr. Allan Bellman and Dr. Tom Brady for always having another *what if*. Thank you to Adrienne, Jennifer, LaVonda, Shawna, and Trisha for always helping find possible responses for *then*. And thank you to Stan, Jane, and Kate for making and eating breakfast for supper on so many occasions because that's all we had in the house.

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CHAPTER ONE: INTRODUCTION

Consider these scenarios familiar to many students and teachers.

A student is asked, "What are you learning about today in class?"
How does the student respond?

A. "Nothing"
B. "Math"
C. "The questions on this worksheet"
D. "Deciding if two figures are congruent"

During class, a student asks the teacher, "Is this going to be on the test?"
How does the teacher respond?

A. Pretends like she didn't hear the question
B. With an eye roll
C. "Everything I say is going to be on the test"
D. "Let's see how what we're doing is connected to today's learning goals"

How often are teachers surprised to find out at the end of a learning episode that students have not actually learned? How often are teachers frustrated by students who ask, "Is this going to be on the test?"

Years of mathematics education research show that establishing and sharing learning goals are important for both teachers and students. The first of NCTM's Mathematics Teaching Practices from _**Principles to Actions**_ is to "establish mathematics goals to focus learning" (2014, p. 10). The mathematical goal of the lesson should not be a secret kept from students. Both students and teachers need to know what math to learn, why to learn it, how it is connected to previous learning, and how it is connected to future learning (NCTM, 2014).

One framework for facilitating meaningful mathematical discourse is the "5 Practices for Orchestrating Productive Mathematics Discussions", in which teachers *anticipate* student strategies for a task, *monitor* students while working, *select* and *sequence* student work to be shared with the whole class, and then *connect* the student work to the mathematical learning that needs to take place in the lesson. Before the 5 Practices can be effective, however, teachers must set learning goals for instruction. "Specifying the mathematical goals for the lesson is a critical starting point for planning and teaching a lesson" (Smith & Stein, 2011, p. 13). When teachers do not have a mathematical goal for a lesson, they think about the lesson in terms of the activities students will do instead of the mathematics that students will know and understand as a result of engaging in the activities (Smith & Stein, 2011). No wonder many students' answers to "what are you learning about today in class" are more focused on an activity they are doing rather than the mathematics they are learning.

"Clarifying, sharing, and understanding goals for learning and criteria for success with learners" is the first of Wiliam and Thompson's key strategies for effective formative assessment (2007, p. 64). They define learning intentions as what students should learn and success criteria as a way to measure whether the learning has happened (Wiliam & Leahy, 2015, p. 31).

"The learning target articulates for students what they are to learn and at the same time provides insight as to how students will be assessed" (Kanold & Larson, 2012, p. 49). What is going to be on the test should not be a surprise to students. Learning targets should inform teachers what content-aligned items to put on the test and should inform students what content-aligned items will be on the test.

This research study builds on the importance of establishing learning goals and clarifying success criteria for students to find out how teachers might provide opportunities for *students* to use learning goals and success criteria formatively in order to know both what they have learned and what they still need to know.

STATEMENT OF THE PROBLEM

Several teachers in the researcher's former math department have been working on clarifying and sharing learning goals and learning targets for and with students for several years now. A few years back, they began to include the learning targets on the unit assessments and organize the problems by learning targets (see Appendices E and F for a before and after precalculus test). The teachers were ready for a next step in improving student learning. As a department, they read Hattie's *Visible Learning for Mathematics* during the year of the research study, and they were interested in trying some of what they were reading as effective strategies for maximizing student learning.

Many interventions tout success in improving student learning. How do teachers decide which ones to try in their classrooms? Hattie has spent years performing meta-analyses of thousands of research studies on millions of students and using effect sizes to compare interventions. Most interventions have an effect size above zero, and so they show some effect on student learning. In order to think about which interventions work better than others, Hattie used the mean effect size of 0.40 to indicate growth at a normal rate in a school year and effect sizes above 0.40 to indicate growth above a normal rate in a school year (Hattie, 2012; Hattie, Fisher, & Fray, 2017).

PURPOSE

Self-reporting progress towards learning targets and setting an expectation for success has an effect size of 1.44, one of the highest effect sizes on student achievement. Hattie suggests that students know how they are going to perform on a test. When given the opportunity to self-report their progress towards a learning target, students set safe expectations. He goes on to say that teachers should not help students reach their predicted level but help them exceed their predicted level (Hattie, May 2012).

The teacher in the research study planned to ask students to self-report (at what level does the student think she is right now?) and predict (at what level does the student expect to be when taking the test during the next class?) on each learning target as Level 1-beginning, Level 2-progressing, Level 3-proficient, or Level 4-exceptional the class period before they take a test. She used analogies of riding a bike and driving a car to establish what learning looks for beginning, progressing, proficient, and exceptional levels (see Appendix G). How well do students self-report or predict their success for each learning target compared to their actual performance on the test? Do they, in fact, know where they are and set safe expectations, ensuring that they do not over-predict how they will do on the test?

When students know what the learning target is, they can compare where they think they are to where the learning target suggests they should be. When they are not where they should be yet, the incongruous progress spurs students to take action on their learning. When students know how they will know when they reach the learning target, they are better able to monitor their progress towards meeting it (Hattie, Fisher, & Fray, 2017). In order to realize the 1.44 effect size from self-reported grades/student expectations, teachers must ensure that students not only know what the learning target is but also how to reach the learning target.

Worked examples also improve student achievement, with an effect size of 0.57. A worked example shows students the steps for solving a math problem (Hattie, Fisher, & Fray, 2017). Might providing worked examples of what each learning target looks like at Level 1-beginning, Level 2-progressing, Level 3-proficient, and Level 4-exceptional not only help students know what the learning target is but also how to reach it, thus having a positive effect on how well students predict their expected success on each learning target (see Appendix H)?

Students using metacognitive strategies as an intervention has an effect size of 0.67. Establishing a norm in the classroom for all learners to share why they are thinking what they are thinking about a problem builds the habit of reflective learning for students, which increases the tendency for students to think about when something does not make sense and take time to figure out why (Hattie, Fisher, & Frey, 2017). Might discussing with students the importance of thinking about how and what they are learning, along with providing students explicit opportunities to know the learning target and how to reach it, have any effect on how well students predict their success on each learning target?

SIGNIFICANCE

Asking students to rate their progress on learning targets before a test takes little class time and is a low-risk request for students with the potential of improving how they think about what they have learned. The rating process could be a wake-up call for some students to recognize what they have not yet learned and take action to learn it. It will likely require students to think more about their progress towards each learning target in the unit more purposefully than they have done so before, which can lead to more deliberate study habits not only in mathematics but also in other subjects.

RESEARCH QUESTIONS

1. Are the students' actual performance levels on test day closer to the student predicted levels or closer to the students' self-reported levels (where they think they are on the day before the test)?

   H_0: The mean difference in actual performance level and student predicted level is equal to the mean difference in actual performance level and the self-reported level (where they think they are on the day before the test).

2. Are there interventions that improve student predictions for how they expect to perform on a test?

   2.1 Do worked examples have any effect on how close student predicted level is to actual performance level?

   H_0: For students who received worked examples, the mean difference in actual performance level and student predicted level is equal to the mean difference for students who did not receive worked examples.

   2.2 Do worked examples and an emphasis on teaching students the importance of metacognition have any effect on how close student predicted level is to actual performance level?

   H_0: For students who received worked examples and a metacognitive treatment, the mean difference in actual performance level and student predicted level is equal to the mean difference for students who did not receive worked examples and a metacognitive treatment.

2.3 Is there a difference between engineering and non-engineering students on how close student predicted level is to actual performance level?

H_0: For students who are in engineering, the mean difference in actual performance level and student predicted level is equal to the mean difference for non-engineering students.

2.4 Do worked examples and metacognitive strategies have any effect on how close student predicted level is to actual performance level for subgroups of students, based on particular self-reported levels and predicted levels?

H_0: For students in subgroups of particular self-reported and predicted levels, the mean difference in actual performance level and student predicted level for those who received worked examples and a metacognitive treatment is equal to the mean difference for those who did not.

3. What are student perceptions around using learning targets to inform student progress in learning?
4. What are teacher perceptions around using learning targets to inform student progress in learning?

CHAPTER TWO: LITERATURE REVIEW

DEFINITIONS

Learning goals or **learning intentions** describe the mathematics that students should know as a result of a learning episode.

Learning targets or **success criteria** or **I can statements** reveal what students should be able to do when they successfully meet the learning goal.

LITERATURE REVIEW

Too often, in classrooms everywhere, students do not know how to respond when they are asked, “What are you learning about today in class?” Too often, in classrooms everywhere, teachers are offended by students who ask, “Is this going to be on the test?”

Establishing and sharing learning goals and targets with students can alleviate some of the tension that comes between students and teachers and the aforementioned questions, but teachers often do not know where to start. Depending on the administrator, the lesson plan form, and the teacher evaluation instrument, teachers are inundated with figuring out what is meant by all sorts of educational jargon surrounding what students should learn and be able to do: learning goal, learning target, learning intention, learning standard, learning outcome, measurable outcome, learner objective, student learning objective (SLO), instructional goal, success criteria, performance criteria, the student will (TSW), the student will be able to (TSWBAT), I can statement, curricular aim, essential question, focus question, etc.

Years of mathematics education research show that establishing and sharing learning goals is important for both teachers and students. In 2014, the National Council of Teachers of Mathematics (NCTM) published *Principles to Actions*, a research-infused endeavor to update NCTM's principles for teaching and learning mathematics and to lay out action-based practices for all mathematics leaders–informing teachers, coaches, administrators, and curriculum specialists how they might ensure all students experience an effective, high-quality mathematics education.

The first of NCTM's Mathematics Teaching Practices is to "establish mathematics goals to focus learning" (2014, p. 10). The mathematical goal of the lesson should not be a secret kept from students. Both students and teachers need to know what math to learn, why to learn it, how it is connected to previous learning, and how it is connected to future learning (NCTM, 2014).

Why Learning Targets Are Important

When teachers establish mathematics goals to focus learning, they not only share lesson goals with students but also help students understand a learning trajectory over time. Teachers ensure students know how their work on the lesson tasks and activities connects to the learning goal, and they use the learning goals to make decisions about what to do next throughout the lesson. Simultaneously, students use the learning goals to make connections to previous and upcoming learning. They use the goals to focus on the math content, self-assess their learning, and seek help when needed (NCTM, 2014).

When teachers know the mathematical goals of the lesson, they are better equipped to enact other Mathematics Teaching Practices, such as selecting a task that promotes reasoning, facilitate meaningful mathematical discourse, and use evidence of student thinking (NCTM, 2014). One framework for facilitating meaningful mathematical discourse is the “5 Practices for Orchestrating Productive Mathematics Discussions”, in which teachers *anticipate* student strategies for a task, *monitor* students while working, *select* and *sequence* student work to be shared with the whole class, and then *connect* the student work to the mathematical learning that needs to take place in the lesson. Before the 5 Practices can be effective, however, teachers must set learning goals for instruction. “Specifying the mathematical goals for the lesson is a critical starting point for planning and teaching a lesson” (Smith & Stein, 2011, p. 13).

When teachers do not have a mathematical goal for a lesson, they think about the lesson in terms of the activities students will do instead of the mathematics that students will know and understand as a result of engaging in the activities (Smith & Stein, 2011). No wonder many students’ answers to “what are you learning about today in class?” are more focused on an activity they are doing rather than the mathematics they are learning.

“Clarifying, sharing, and understanding goals for learning and criteria for success with learners” is the first of Wiliam and Thompson’s key strategies for effective formative assessment (2007, p. 64). By 2015, Wiliam reworded the strategy as “clarifying, sharing, and understanding learning intentions and success criteria” (Wiliam & Leahy, 2015, p. 27). Wiliam & Leahy also bemoan teachers who talk about their lesson in terms of what students are going to do rather than what students should learn. They define learning intentions as what students should learn and success criteria as a way to measure whether the learning has happened (Wiliam & Leahy, 2015).

Clear learning goals help inform teachers when planning the tasks that will be appropriate for students to engage in the mathematics. Clear learning goals inform formative assessment moves for a lesson, giving teachers insight during the lesson to make instructional decisions that move the learning forward (Boston, et.al, 2017). "Innovations that include strengthening the practice of formative assessment produce significant and often substantial learning gains" (Black & Wiliam, 1998, p. 141). Teachers who use formative assessment regularly focus more on what the student is learning than on what the student is doing (Wiliam & Thompson, 2007).

Clear learning goals help students embrace learning. A student's brain is wired to learn when the student's brain finds meaning in that learning. Meaning occurs when learning is connected to goals. When students can tell that activities and tasks are connected to the learning goals, their brains are more likely to allow work on the task, and they complete the task more quickly (Sousa & Tomlinson, 2011).

Sharing learning goals with students communicates teacher belief and a growth mindset that all students are able to meet the goals. "Goals can support equitable instruction by setting clear and high expectations" (Boston, et al., 2017, p. 25).

Writing Student-Friendly Learning Targets

"To use knowledge flexibly, students need to understand what they are learning" (Horn, 2012, p. 36). Learning targets should be shared with students using student-friendly language (Bailey & Jakicic, 2012). They should be "stated clearly in age-appropriate language", and teachers should "clarify any questions students may have about them" (Sousa, 2015, p. 92). While student-friendly language is important, teachers should be sure that the original intent of the standard is not lost when rewriting for students (Ainsworth, 2015). Academic language can be included in a learning target written for students, but teachers should ensure that students understand the academic language. Bailey and Jakicic have established that writing learning targets in the form of "I can …" statements increase student ownership of the learning. Writing learning targets so that students will know how to show they are successful helps students self-assess their progress towards successfully meeting the learning targets (2012).

In order to ensure that learning targets are written so that students understand, the teacher could ask a few students to quietly read the target and describe the learning target in their own words. The teacher can use what students have written to calibrate their understanding of the learning target. If students have written widely varied descriptions of the target, then the teacher should likely reword the learning target to ensure student understanding (Popham, 2008). Student understanding of the learning target is essential, as students who do not understand the learning target are unable to assess their progress towards meeting the target (Heritage, 2018).

Sharing Learning Targets with Students

Educators do not always agree on when and how learning targets should be shared. For example, some think that learning targets should be posted in the class so that students can see them and reference them while the class activities and tasks are focused on those targets (Popham, 2008). Others believe that "sometimes telling the students where they are going completely spoils the journey!" (Wiliam, 2011, p. 57). Many teacher evaluation forms have a checkbox for teachers sharing and posting the learning target at the beginning of class, which often results in a perfunctory attempt by teachers of ensuring students know what they are to learn. Teachers should discern when sharing the learning target at the beginning of the lesson will support student learning and when it will taint student learning, and share accordingly (Wiliam, 2011).

In the researcher's former school, teachers were required to post the learning target at the beginning of class and keep it visible throughout the class. However, the researcher found, like Wiliam, that the learning target often gave away what students were invited to figure out as a result of the class tasks and activities. Sharing the learning target before the lesson would be like sharing the punchline to a joke at the beginning of the joke instead of the end. The researcher worked with the assistant principal on a compromise that resulted in sharing at the beginning of class the math practice goal that students would likely use, such as I can "look for and express regularity in repeated reasoning" (NGA, 2010, p. 8), to engage in the math content that would be revealed by the end of class, such as I can "derive the equation of a circle of given center and radius using the Pythagorean Theorem" (NGA, 2010, p. 78). During the learning episode, students are provided the opportunity to make connections between a right triangle with a hypotenuse that is the radius of a circle, the Pythagorean Theorem, and the equation of the circle instead of being told at the beginning of the lesson that the equation of the circle is related to the Pythagorean Theorem.

The *Illustrative Mathematics 6–8 Math* curriculum alleviates the problem of spoiling the journey by including both student-facing learning goals and student-facing learning targets. Learning goals are written in the form of "Let's. . ." to invite students into the work to be done and to focus learning at the beginning of class without revealing the mathematical relationships that will be uncovered during the lesson. Learning targets are written in the form of actionable "I can. . ." statements to help students connect the goal to the math they are learning. The cool-down for each lesson gives students the opportunity to show and assess their progress in reaching the target (Open Up Resources, 2017a). For example, the learning goal for an eighth-grade lesson on congruent figures polygons is

“Let’s decide if two figures are congruent.” The learning target is “I can decide using rigid transformations whether or not two figures are congruent.” While the learning goal focuses the learning on determining whether two figures are congruent, it does not reveal how to determine whether two figures are congruent, which is uncovered through the activities in the lesson (Open Up Resources, 2017b).

Learning Targets Inform Assessment

“The learning target articulates for students what they are to learn and at the same time provides insight as to how students will be assessed” (Kanold & Larson, 2012, p. 49). Learning targets “drive the creation of unit assessments (pre-, post-, and quick progress checks)” (Ainsworth, 2015, p. 21). What is going to be on the test should not be a surprise to students. The first indicator on Kanold & Larson’s assessment evaluation tool is “identification and emphasis on learning targets” (see Appendix I). Level 1 (not present) suggests that “learning targets are unclear or absent from the assessment instrument. Too much attention is given to one target.” Level 4 (fully present) suggests that “clearly stated learning targets are on the assessment and connected to the assessment questions” (Kanold & Larson, 2012, p. 94). Learning targets should inform teachers what content-aligned items to put on the test and should inform students what content-aligned items will be on the test.

Teachers can help students better understand learning targets by sharing with students how the learning target will be assessed. Sharing example test problems is an ideal way to improve student understanding of the learning target. Sharing the types of test items that might be used to assess a learning target and why that type of item was chosen adds to student understanding of the learning target. Sharing a novice worked example alongside a proficient worked example can also illuminate student understanding of the learning target (Popham, 2008). Many teachers object to worked examples because students read through them without trying to understand them. Learning with worked examples is more effective when students are encouraged to self-explain the steps in the problem. Teachers are integral to training students how to self-explain (Renkl, 2014). "With this brain-friendly approach, formative assessments become practice-for-mastery activities rather than anxiety-producing episodes" (Sousa, 2015, p. 92).

Students must partner with the teacher in reaching towards the learning target, and they can also help each other better understand learning targets. "It helps to make the students fully aware of the learning intentions and success criteria, of the value of deliberate practice, and of what to do when they do not know what to do" (Hattie, 2012, p. 111). Wiliam calls out these processes in two of his five key strategies of formative assessment: "activating learners as instructional resources for each other" and "activating learners as owners of their learning" (2011, p. 2). Students become more interested in learning when they can gauge their progress towards meeting the learning goal and know what steps to take to improve (Sousa, 2015).

Exit tickets are one way for students and teachers to gather information about what students can know and do as a result of engaging in a learning episode. Exit tickets are usually given at the end of a lesson as an opportunity for students to reflect on their learning and for teachers to have information to make instructional adjustments based on student learning. Asking students to complete such prompts as "I learned … " and " My question is …" and "What I learned today is important because …" gives students and teachers insight into the learning that has occurred and what learning should come next (Baron, 2016).

Learning Targets Embedded in Learning Progressions

Ultimately, the learning targets for one lesson should not be isolated from the learning targets for another lesson. Over time, teachers and students need to have an idea of the big picture of learning (Wiliam & Leahy, 2015). Overarching learning goals give insight into what students should learn throughout a course; unit learning goals give insight into what students should learn during a unit; and lesson learning goals give insight into what students should learning during a lesson (Hiebert and Stigler, 2017).

Students will have a better idea of what they are to learn when learning targets are embedded within learning progressions (Popham, 2008). Working towards a learning target is not a linear process for all students, but the plan surrounding a learning target should be inclusive of all students (Hattie, 2012). Teachers can use a learning progression to analyze student strategies for solving a task, make instructional adjustments based on those responses, and move all students towards procedural fluency (Ebby & Pettit, 2017). Knowing where the learning target falls within the progression of learning helps students make decisions about what they do not yet know and thus adjust how and what they practice in order to reach the learning target. Learning progressions can provide information about the skills needed to reach a target as well as enrichment opportunities for those who have already reached the target. Knowing how the learning target is connected to prior and future learning is essential (Popham, 2008).

Learning progressions not only inform the formative assessment process, they help teachers plan the formative assessment process. Teachers use the learning progression to determine what questions to ask, when to ask them, and what to do next depending on student responses. “If a ship without a rudder is, by definition, rudderless, then formative assessment without a learning progression often becomes plan-less” (Popham, 2011, p. 24).

Students can be helpful in co-constructing and revising learning progressions as they become more aware of their learning. Teachers should remember that learning progressions are not one-size-fits-all. Learning progressions vary from state to state and from one set of curricular materials to another. Students may or may not engage in a learning progression in the given sequence, as many factors, prior knowledge in particular, affect how and what students learn (Wiliam & Leahy, 2015).

Writing learning progressions is challenging, time-consuming work for teachers. Not all learning targets need to be situated in a learning progression. Whether the learning target is a skill that will take longer than one class to learn, whether the learning target will be used in additional units or courses and connected to real-world situations, whether the skill will be assessed on high-stakes tests, and ultimately whether the learning target is really important to student learning should all be taken into consideration when a teacher decides whether to write a learning progression (Popham, 2011).

Affecting Student Learning

Many interventions tout improving student learning. How do teachers decide which ones to try in their classrooms? Hattie has spent years performing meta-analyses of thousands of research studies on millions of students and using effect sizes to compare interventions. Most interventions have an effect size above zero, and so they show some effect on student learning. In order to think about which interventions work better than others, Hattie used the mean effect size of 0.40 to indicate growth at a normal rate in a school year and effect sizes above 0.40 to indicate growth above a normal rate in a school year (Hattie, 2012; Hattie, Fisher, & Fray, 2017).

Self-reporting progress towards learning targets and setting an expectation for success has an effect size of 1.44, one of the highest effect sizes on student achievement (Hattie, 2017). Students who are able to rate their progress on learning targets as beginning or proficient show how well they understand the learning target and their progress towards meeting it. "When there is a gap between where they are and where they want to be, it creates cognitive dissonance", pushing students to learn more and work harder so that they can close the gap. Teachers should provide students clear indications of what it means to meet a learning target so that students will know how to improve (Hattie, Fisher, & Frey, 2017, p. 57).

Worked examples also improve student achievement, with an effect size of 0.57. A worked example shows students the steps for solving a math problem. Teachers should make it clear to students whether the worked examples are correct or incorrect solutions to the problem so that students do not unintentionally learn incorrect methods for solving problems. Analyzing worked examples can help students think about why the problem is solved the way it is and move students towards explanations for how to solve the problem instead of only focusing on the answer (Hattie, Fisher, & Frey, 2017).

Students using metacognitive strategies as an intervention has an effect size of 0.67. Establishing a norm in the classroom for all learners to share why they are thinking what they are thinking about a problem builds the habit of reflective learning for students, which increases the tendency for students to think about when something does not make sense and take time to figure out why. Some students will more naturally think about their learning than other students (Hattie, Fisher, & Frey, 2017). In one research study, learning experts who shared their thinking while learning were found to frequently reflect on how well they were learning, what they still needed to know, and how well what they were learning jived with what they already knew (Bransford, Brown, & Cocking, 2001). Teachers need to purposefully teach metacognitive strategies to the class and provide deliberate opportunities for reflecting on learning so that all students can advantageously use metacognitive strategies to improve learning (Hattie, Fisher, & Frey, 2017). When the teacher models the use of metacognitive strategies and discusses the strategies with students as they learn to use them, students eventually use the strategies themselves without being prompted by the teacher (Bransford, Brown, & Cocking, 2001).

CONNECTING TO RESEARCH PROJECT

How often are teachers surprised to find out at the end of a learning episode that students have not actually learned? How often are teachers frustrated by students who ask, "Is this going to be on the test?"

This research study builds on the importance of establishing learning goals and clarifying success criteria for students to find out how teachers might provide opportunities for students to use learning goals and success criteria formatively in order to know both what they have learned and what they still need to know.

CHAPTER THREE: METHODOLOGY

PURPOSE AND RESEARCH QUESTIONS

The purpose of this mixed methods research study is to look at how well students predict their expected level of success on learning targets for an upcoming test when they are given the chance to rate themselves before they take the test and whether treatments such as worked examples and metacognitive strategies move predicted levels closer to actual performance on the test. According to Hattie, self-reporting progress towards learning targets and setting an expectation for success has a high effect on student achievement. Hattie suggests that students know how they are going to perform on a test. When given the opportunity to self-report their progress towards a learning target, students set safe expectations (Hattie, May 2012).

The teacher who participated in the research study asked students to rate themselves as Level 1-beginning, Level 2-progressing, Level 3-proficient, or Level 4-exceptional on each learning target before they took a test. In order for students to have some measure for each rating, she used analogies of riding a bike and driving a car to establish what learning looks for beginning, progressing, proficient, and exceptional (see Appendix G).

When students know what the learning target is, they can compare where they think they are to where the learning target suggests they should be. When they are not where they should be yet, the incongruous progress spurs students to take action on their learning. When students know how they will know when they reach the learning target, they are better able to monitor their progress towards meeting it (Hattie, Fisher, & Fray, 2017). In order to realize the 1.44 effect size from self-reported grades/student expectations, teachers must ensure that students not only know what the learning target is but also how to reach the learning target.

According to Hattie, worked examples also improve student achievement (2017). The researcher considered whether providing students with worked examples of what each learning target looks like at Level 1-beginning, Level 2-progressing, Level 3-proficient, and Level 4-exceptional not only helped students know what the learning target is but also how to reach it, thus having a positive effect on how well students predict their success on each learning target (see Appendix H.)

Hattie also suggests that metacognitive strategies improve student achievement and that providing students opportunities to reflect on their learning can further metacognition (2017, p. 39). The researcher also considered whether the teacher discussing with students the importance of thinking about how and what they are learning and also providing students explicit opportunities to know the learning target and how to reach it had any effect on how well students predict their success on each learning target.

In considering how well students self-reported their progress towards the learning target the following research questions were examined.

1. Are the students' actual performance levels on test day closer to the student predicted levels or closer to the students' self-reported levels (where they think they are on the day before the test)?

H_0: The mean difference in actual performance level and student predicted level is equal to the mean difference in actual performance level and the self-reported level (where they think they are on the day before the test).

2. Are there interventions that improve student predictions for how they expect to perform on a test?

2.1 Do worked examples have any effect on how close student predicted level is to actual performance level?

H_0: For students who received worked examples, the mean difference in actual performance level and student predicted level is equal to the mean difference for students who did not receive worked examples.

2.2 Do worked examples and an emphasis on teaching students the importance of metacognition have any effect on how close student predicted level is to actual performance level?

H_0: For students who received worked examples and a metacognitive treatment, the mean difference in actual performance level and student predicted level is equal to the mean difference for students who did not receive worked examples and a metacognitive treatment.

2.3 Is there a difference between engineering and non-engineering students on how close student predicted level is to actual performance level?

H_0: For students who are in engineering, the mean difference in actual performance level and student predicted level is equal to the mean difference for non-engineering students.

2.4 Do worked examples and metacognitive strategies have any effect on how close student predicted level is to actual performance level for subgroups of students, based on particular self-reported levels and predicted levels?

H_0: For students in subgroups of particular self-reported and predicted levels, the mean difference in actual performance level and student predicted level for those who received worked examples and a metacognitive treatment is equal to the mean difference for those who did not.

3. What are student perceptions around using learning targets to inform student progress in learning?
4. What are teacher perceptions around using learning targets to inform student progress in learning?

POPULATION AND SAMPLING

This research study took place at Northwest Rankin High School, a suburban school in Rankin County School District near Jackson, Mississippi. Sixty-five of the sixty-six students enrolled in Ms. Baird's three sections (A4, B2, and B3) of Advanced Math Plus (precalculus) took part in the study. Students who enrolled in Ms. Baird's precalculus class have shown interest in taking Advanced Placement (AP) Calculus their senior year. Northwest Rankin High School takes seriously the stance of the College Board on access and equity by offering open enrollment for all AP and pre-AP courses. While it should be noted that many of Ms. Baird's students rank at the top of their class, it should also be noted that any student could self-elect to participate in the class.

Ms. Baird and her students were selected to participate in the study because of the progress Ms. Baird made with students on sharing learning targets both in class and on unit assessments throughout the first semester. Additionally, Ms. Baird has shown interest in taking a next step in clarifying and sharing learning targets with students and was willing to provide opportunities for students to rate their progress on learning targets during the second semester. Students were not asked to identify themselves in any manner and thus their anonymity has been protected.

All of Ms. Baird's students were classified as juniors. 45% are female. 79% are white. 30% have taken at least one class in the NWRHS Engineering Academy. See Table 3.1 for a breakdown of student demographics by section.

Table 3.1

Student Demographics

Section	Number (n)	Female/Male %	White/Black/Hispanic/Asian %	Engineering Academy %
1 (A4)	18	44%/56%	72%/22%/6%/0%	11%
2 (B2)	25	40%/60%	80%/16%/0%/4%	40%
3 (B3)	23	52%/48%	82%/9%/0%/9%	35%
Total	66	45%/55%	79%/15%/1%/5%	30%

INSTRUMENTATION

This research study used a mixed methods, sequential explanatory design to study the success of students self-reporting and predicting levels on learning targets, with and without leveled worked examples, with and without emphasizing metacognitive strategies. Quantitative data were collected before qualitative data.

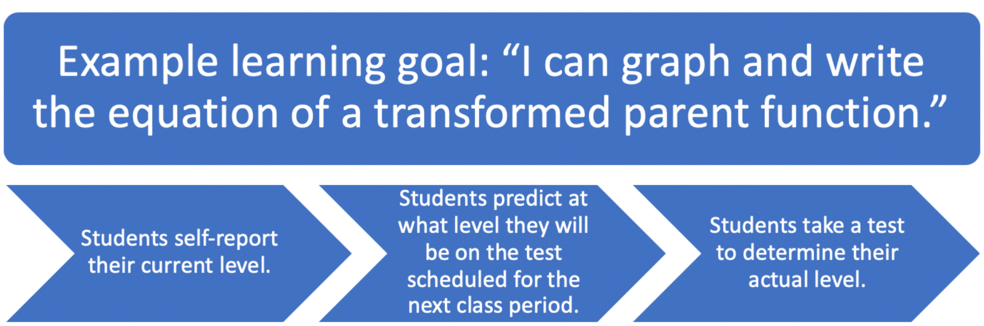
Students completed a Google Form at the beginning of the class period before the test for three tests during the second semester. They recorded the student number assigned to them by their teacher and rated both their self-reported level (Level 1-

beginning, Level 2-progressing, Level 3-proficient, or Level 4-exceptional) for each learning target (at what level does the student think he is right now?) and their predicted level for test day (at what level does the student expect to be when taking the test during the next class?) (see Appendix J).

The teacher determined what percentage correct constituted beginning, progressing, proficient, or exceptional for each learning target. For example, on a particular learning target, 0-50% could be considered Level 1-beginning, 51-70% Level 2-progressing, 71-90% Level 3-proficient, and 91-100% Level 4-exceptional. The percentages might be different on another learning target. Ms. Baird completed a spreadsheet after grading each test, recording the student number and actual level for each learning target (at what level did the student actually perform on the test?). Figure 3.1 shows the process that students completed for each learning target on the test.

Figure 3.1

Process Students Completed for Each Learning Target on the Test



After the third test, students completed a Google Form survey to share how they used learning targets and whether rating their progress and/or the worked examples were helpful in their learning (see Appendix K). The researcher interviewed Ms. Baird at the end of the research study to find out her thoughts on the research study and to see what aspects, if any, she might continue during another semester, class, or school year (see Appendix M).

Procedure and Time Frame

Ms. Baird collected data for 3 unit assessments during the second semester of the 2017-2018 school year.

Before the first test of the second semester, students self-reported the level of their current progress towards each learning target and predicted the level of their success on the test as Level 1-beginning, Level 2-progressing, Level 3-proficient, or Level 4-exceptional (see Appendix J). Students were given analogies for what is meant by beginning, progressing, proficient, and exceptional (see Appendix G). The teacher reported the actual level of success on the test for each learning target.

For the second test, the teacher provided example problems of what each learning target looks like at each level along with the worked solutions (see Appendix H.) During this phase, the teacher discussed the importance of metacognition with one of the sections but not the others. Students self-reported the level of their current progress towards each learning target and predicted the level of their success on the test. The teacher reported the actual level of success on the test for each learning target.

For the third test, the teacher provided leveled example problems with worked solutions and discussed the importance of metacognition with all three sections. Students self-reported the level of their current progress towards each learning goal and predicted the level of their success on the test. The teacher reported the actual level of success on the test for each learning target.

Since the problems on the test are already sorted by learning target, the teacher was easily able to determine the total points earned out of the total point possible for each student for each learning target and then correlate the total points earned with Level 1-beginning, Level 2-progressing, Level 3-proficient, and Level 4-advanced. The researcher then considered the difference of the actual level of student success on the test and the self-reported level of success for each learning target (denoted *self-reported change*) and also the difference of the actual level of student success on the test and the student predicted level of success for each learning target (denoted *predicted change*).

Each student was assigned a student number for use during the research study to ensure that student anonymity was preserved throughout the study. Students recorded their student number in the three self-assessment surveys, and the teacher reported the test data to the researcher using the same student number so that the researcher could determine any statistical significance between the students' self-reported level, predicted level, and their actual level of success on the test.

At the end of the three tests, students completed an anonymous survey about the process to find out whether they used the self-reported ratings and worked examples and whether their confidence level and/or achievement improved based on their use (see Appendix K). Finally, the researcher interviewed the teacher about the process to see whether she had any anecdotal evidence for whether the self-reported ratings, worked examples, and emphasis on metacognition made any difference on student learning and might have any effect on her future practices in the classroom (see Appendix M).

Analysis Plan

For each of the units (7, 8, and 9) and each of the learning targets (7_1, 7_2, 7_3, 7_4, 8_1, etc.) the students submitted a self-reported level from 1 to 4 (at what level does the student think she is right now?) and a predicted level from 1 to 4 (at what level does the student expect to be when taking the test during the next class?). The teacher reported an actual level from 1 to 4 (at what level did the student actually perform on the test?). No instrument was used to verify the accuracy of the student self-reported level; it was based only on each student's evaluation of where he thought he was at that time. Table 3.2 shows raw sample student data for Unit 7.

Table 3.2

Sample Student Data, Unit 7 Raw

Student Number	7_1 self-reported level	7_1 predicted level	7_1 actual level	7_2 self-reported level	7_2 predicted level	7_2 actual level	7_3 self-reported level	7_3 predicted level	7_3 actual level	7_4 self-reported level	7_4 predicted level	7_4 actual level
100	3	4	3	2	4	4	3	4	4	2	3	4
101	4	4	3	4	4	2	4	4	3	3	4	3
102	3	4	3	2	3	3	3	4	4	2	4	3

To determine how well students self-reported and predicted their progress towards the learning target, the researcher found the difference for each learning target of the self-reported level (at what level does the student think she is right now?) and the actual level of student success (at what level did the student actually perform on the test?), which from this point on will be called *self-reported change*, and also the difference of the predicted level of success for each learning target and the actual level of student success, which from this point on will be called *predicted change* (see Table 3.3).

Table 3.3

Sample Student Data, Unit 7 Learning Targets Self-Reported Change and Predicted Change

Student Number	7_1 self-reported change	7_1 predicted change	7_2 self-reported change	7_2 predicted change	7_3 self-reported change	7_3 predicted change	7_4 self-reported change	7_4 predicted change
100	0	-1	2	0	1	0	2	1
101	-1	-1	-2	-2	-1	-1	0	-1
102	0	-1	1	0	1	0	1	-1

Note. *Self-reported change* is the difference between self-reported level and actual performance level on test; *predicted change* is the difference between predicted level and actual performance level on test.

A value of 0 indicates that the student actually performed on the test at the same level they self-reported or predicted. A value of -1 indicates that the student performed one level lower than the level self-reported or predicted; -2 indicates an actual performance two levels lower than the level self-reported or predicted. A value of 1 indicates that the student performed one level higher than the level self-reported or predicted; 2 indicates an actual performance two levels higher than the level self-reported or predicted.

The mean of the differences between self-reported and actual levels as well as the mean of the differences between predicted and actual levels for the learning targets on each unit test were used to determine a single self-reported change and a single predicted change for each student by each unit (see Table 3.4).

Table 3.4

Sample Student Data, Unit Self-reported Change and Predicted Change

Student Number	Unit 7 self-reported change	Unit 7 predicted change	Unit 8 self-reported change	Unit 8 predicted change	Unit 9 self-reported change	Unit 9 predicted change
100	1.25	0	0.6	-0.2	0.83	-0.17
101	-1	-1.25	-0.8	-1.8	0.67	-0.33
102	0.75	-0.5	0	-0.6	0.83	0.17

Note. *Self-reported change* is the difference between self-reported level and actual performance level on test; *predicted change* is the difference between predicted level and actual performance level on test.

A value of 0 indicates that, on average, the student actually performed around the same level self-reported or predicted for all learning targets on the test. A negative value indicates that, on average, the student actually performed lower than the self-reported or predicted level. A positive value indicates that, on average, the student actually performed higher than the self-reported or predicted level for all learning targets on the test.

Students who were absent on the day before any one of the three tests and did not complete the Google Form were removed from the quantitative data analysis. Out of the 65 students who agreed to participate in the research study, the researcher was able to collect all quantitative data for 41 students who were present for all three review days and all three test days. To consider how well students self-reported their progress towards the learning target, the researcher used descriptive statistics, t-tests, one-way ANOVA tests, and chi-square tests of independence to analyze the quantitative data.

Question 1

Are the students' actual performance levels on test day closer to the student predicted levels or closer to the students' self-reported levels (where they think they are on the day before the test)?

A paired t-test with a critical alpha level of 0.05 showed any statistical significance between students self-reported level and predicted level. The self-reported, predicted, and actual success levels for Units 7, 8 and 9 were used for the t-test. The researcher used the t-test to determine whether the difference between self-reported change and predicted change is statistically significant.

Question 2

Are there interventions that improve student predictions for how they expect to perform on a test? Interventions such as worked examples and a metacognitive treatment were considered.

Question 2.1

Do worked examples have any effect on how close student predicted level is to actual performance level?

A one-way ANOVA with a critical alpha level of 0.05 showed any statistical significance for students predicting their level of success when students had the opportunity to assess their progress throughout the unit using worked examples. The researcher used the ANOVA comparison followed by a Tukey-Kramer HSD Comparison to determine how close student predicted level is to actual performance level for students who received worked examples compared to students who did not receive worked examples.

Question 2.2

Do worked examples and an emphasis on teaching students the importance of metacognition have any effect on how close student predicted level is to actual performance level?

All students received worked examples in Unit 8 and Unit 9. For the metacognitive treatment, the teacher had conversations in class with the students about how research shows that metacognition improves student achievement. One section, B2, had the metacognitive treatment for Unit 8. All three sections had the metacognitive treatment for Unit 9. An ANOVA comparison with a critical alpha level of 0.05 showed any statistical significance for how close student predicted level is to actual performance level for students who received worked examples and a metacognitive treatment compared to students who did not receive worked examples and a metacognitive treatment.

Question 2.3

Is there a difference between engineering and non-engineering students on how close student predicted level is to actual performance level?

Engineering students have used learning targets not only in math but also in engineering. Is there a difference on how close student predicted level is to actual performance level for students who take engineering classes compared to students who do not take engineering classes? An ANOVA comparison with a critical alpha level of 0.05 showed any statistical significance for engineering student success in predicted level when compared to non-engineering students.

Question 2.4

Do worked examples and metacognitive strategies have any effect on how close student predicted level is to actual performance level for subgroups of students, based on particular self-reported levels and predicted levels?

For subgroups such as students who self-reported Level 3 and predicted Level 4, or self-reported Level 2 and predicted Level 3, data were analyzed using a chi-square test of significance by decomposing results in each category into performed at a lower level, performed at self-reported level, performed at predicted level, or performed at a higher level to determine whether there is any difference on how close predicted progress is to actual performance for students who received the worked examples and metacognitive treatment compared to those who did not receive the treatment.

Question 3

What are student perceptions around using learning targets to inform student progress in learning?

Question 4

What are teacher perceptions around using learning targets to inform student progress in learning?

The anonymous survey that students completed at the end of the research study and the teacher interview produced qualitative data that the researcher used to gauge student and teacher impressions on the effect of students predicting their level on learning targets with or without worked examples, and with or without an emphasis on metacognition. Responses from Likert scale questions were collected on a bar graph to determine whether any responses are significant. The researcher analyzed open-ended qualitative questions by coding. The researcher compared student and teacher impressions to the results of the analysis on the quantitative data.

Validity and Reliability

All but one of Ms. Baird's precalculus students agreed to participate in the study. While it was convenient to survey students who have the same teacher, it was also purposeful. Ms. Baird used learning targets in all three sections of her precalculus classes during the first semester by sharing the learning targets with students for each unit and including them on all tests. Consequently, the results from this research study are not generalizable to all math students. Including students from a different teacher who were not already using learning targets to inform learning and assessment could have very different results.

The three sections of precalculus were all taught at the same school and by the same teacher. The researcher used a non-paired t-test with a critical alpha level of 0.05 with the numerical Algebra 2 course grade and the numerical precalculus semester grades to determine whether the three sections were reasonably comparable and ensure that the results of the study are reliable. The teacher worked with all three sections in the same manner throughout the research study except for the second phase of the study. During this phase, she both used worked examples and discussed the importance of metacognition to help predict success with her second section (B2) but not the others. Does an emphasis on teaching students the importance of metacognition have any effect on how close predicted progress is to actual performance? On the third test, the teacher discussed the importance of metacognition and using worked examples to help predict success with all three sections.

Mathematics educator classmates of the researcher provided feedback on the survey questions that were used with students and interview questions that were used with the teacher. Ms. Baird calibrated what percentage correct constitutes Level 1-beginning, Level 2-progressing, Level 3-proficient, or Level 4-exceptional for each learning target with a former Northwest Rankin High School precalculus teacher.

Scope and Limitations

The students in Ms. Baird's classes were juniors. All but five students had a geometry class that used learning targets in class and on the test when they were in the ninth grade. No student had an Algebra 2 class that used learning targets on the test when they were in the 10th grade. Some of them were engineering students who have used learning targets in engineering classes as well as math classes. Even though students started precalculus with varying experiences of using learning targets individually and in previous classes, all of the students used learning targets in class and on the test during the entire year of precalculus. It could be interesting to repeat this study in the same school with a different teacher or a different course and in a different school with students who had not previously focused on learning targets during class or had learning targets on their tests, but that is beyond the scope of this research project.

In this study, students self-reported the level they thought they were the day before the test and predicted the level they expected to be when taking the test during the next class. No instrument was used to verify the accuracy of the student self-reported level; it was based only on each student's evaluation of where he thought he was at that time. It could be interesting to repeat this study with the same students using some sort of instrument to verify the accuracy of the students' self-reported levels.

CHAPTER FOUR: RESULTS

PURPOSE

This research study sought to determine how well students predict success on learning targets for an upcoming test when they are given the chance to rate themselves before they take the test and whether treatments such as worked examples and metacognitive strategies move predicted levels closer to actual performance on the test. Additionally, the researcher considered whether there is a difference in the ability to predict success level between engineering and non-engineering students since engineering students use learning targets in both their math and engineering classes. Through questions on a student Google form and for a teacher interview, the researcher sought to determine student and teacher perceptions around using learning targets to inform student progress in learning.

POPULATION AND SAMPLING

This research study took place at Northwest Rankin High School, a suburban school in Rankin County School District near Jackson, Mississippi. Sixty-five of the sixty-six students enrolled in Ms. Baird's three sections (A4, B2, and B3) of Advanced Math Plus (precalculus) took part in the study.

All of Ms. Baird's students were classified as juniors. 45% are female. 79% are white. 30% have taken at least one class in the NWRHS Engineering Academy. See Table 4.1 for a breakdown of student demographics by section.

Table 4.1

Student Demographics

Section	Number (n)	Female/Male %	White/Black/Hispanic/Asian %	Engineering Academy %
1 (A4)	18	44%/56%	72%/22%/6%/0%	11%
2 (B2)	25	40%/60%	80%/16%/0%/4%	40%
3 (B3)	23	52%/48%	82%/9%/0%/9%	35%
Total	66	45%/55%	79%/15%/1%/5%	30%

VALIDITY AND RELIABILITY

The researcher used students' final Algebra 2 grades and their two semester precalculus grades to determine whether the three precalculus sections in the study were reasonably comparable to ensure that the results of the study are reliable. 92% of the students had the same Algebra 2 teacher. All students were in Ms. Baird's precalculus sections, and thus she assigned all student grades throughout the year. The data were analyzed using a one-way ANOVA with statistical significance set at an alpha level of 0.05 to measure the influence of the independent variable, class section, on the dependent variables, final Algebra 2 grade (see Table 4.2), semester one precalculus grade (see Table 4.3), and semester two precalculus grade (see Table 4.4). The resulting p-values show no statistically significant difference between Ms. Baird's three precalculus sections.

Table 4.2

One-Way Analysis of Variance of Final Algebra 2 Grade by Precalculus Section

Source	*df*	*SS*	*MS*	*F*	*p*
Between groups	2	78.26	39.13	0.36	0.699
Within groups	56	6021.88	107.53		
Total	58	6100.14			

Table 4.3

One-Way Analysis of Variance of Semester 1 Precalculus Grades by Precalculus Section

Source	*df*	*SS*	*MS*	*F*	*p*
Between groups	2	155.09	77.54	0.57	0.568
Within groups	62	8508.45	137.23		
Total	64	8663.54			

Table 4.4

One-Way Analysis of Variance of Semester 2 Precalculus Grades by Precalculus Section

Source	*df*	*SS*	*MS*	*F*	*p*
Between groups	2	202.18	101.09	0.75	0.477
Within groups	62	8314.07	134.10		
Total	64	8516.25			

The researcher examined test scores from the previous three years for Units 7, 8, and 9 to determine whether student scores on the tests were reasonably comparable to eliminate the possibility that the difficulty of the content influenced student performance. Ms. Baird taught precalculus last year; Ms. Dolf taught precalculus the two years before that. Both teachers used the same instrument to assess students each year for Units 7, 8, and 9. Descriptive statistics for test scores are included in Table 9.

Table 4.5

Descriptive Statistics of Test Grades by Unit, Ms. Baird and Ms. Dolf

Unit	Minimum	Maximum	Mean	SD
7	50	100	85.27	11.21
8	50	100	84.83	12.31
9	49	100	82.21	13.77

The data were analyzed using a one-way ANOVA with statistical significance set at an alpha level of 0.05 to measure the influence of the independent variable, unit number, on the dependent variable, test grade. Test grades from the current and previous precalculus teachers, Ms. Baird and Ms. Dolf, for the past three years showed no statistical difference between tests (see Table 4.6).

Table 4.6

One-Way Analysis of Variance of Test Grades by Unit, Ms. Baird and Ms. Dolf

Source	***df***	***SS***	***MS***	***F***	***p***
Between groups	2	639.61	319.81	2.06	0.13
Within groups	358	54143.49	155.58		
Total	350	54783.10			

TEST RESULTS

The broad research question considers how well students predict the level at which they expect to perform on a learning target on a test and whether there are interventions that improve student predictions.

Question 1

Are the students' actual performance levels on test day closer to the student predicted levels or closer to the students' self-reported levels (where they think they are on the day before the test)?

H_0: The mean difference in actual performance level and student predicted level is equal to the mean difference in actual performance level and the self-reported level (where they think they are on the day before the test).

For each of the units (7, 8, and 9) and each of the learning targets (7_1, 7_2, 7_3, 7_4, 8_1, etc.) the students submitted a self-reported level from 1 to 4 (at what level does the student think he is right now?) and a predicted level from 1 to 4 (at what level does the student expect to be when taking the test during the next class?). The teacher reported an actual level from 1 to 4 (at what level did the student actually perform on the test?). Complete quantitative data were secured for 41 of the 65 students who agreed to participate in the research study.

Appendix N has a list of each content learning target by unit. Table 4.7 shows descriptive statistics for self-reported change and predicted change by learning target.

Table 4.7

Descriptive Statistics for Self-Reported Change and Predicted Change by Learning Target

Learning Target	Minimum Self-Reported Change	Maximum Self-Reported Change	Mean Self-Reported Change	SD Self-Reported Change	Minimum Predicted Change	Maximum Predicted Change	Mean Predicted Change	SD Predicted Change
7_1	-2	1	-0.22	0.82	-3	2	-0.63	0.80
7_2	-3	2	0.12	0.95	-3	1	-0.27	0.81
7_3	-1	2	0.37	0.83	-1	2	-0.10	0.80
7_4	-2	2	0.32	1.06	-2	1	-0.24	0.89
8_1	-1	2	0.17	0.77	-2	1	-0.41	0.84
8_2	-3	1	-0.22	1.01	-3	1	-0.68	0.93
8_3	-2	2	-0.02	0.99	-2	1	-0.59	0.89
8_4	-2	1	-0.61	0.80	-3	1	-1.15	0.94
8_5	-2	2	-0.29	1.23	-3	1	-0.90	1.24
9_1	-1	2	0.49	0.68	-1	1	-0.05	0.55
9_2	-1	2	0.46	0.71	-1	1	-0.07	0.61
9_3	-1	1	0.20	0.71	-2	0	-0.39	0.54
9_4	-2	2	0.07	0.75	-3	1	-0.56	0.78
9_5	-1	1	0.39	0.63	-1	1	-0.15	0.57
9_6	-1	2	0.27	0.84	-2	1	-0.32	0.72

Note. *Self-reported change* is the difference between self-reported level and actual performance level on test; *predicted change* is the difference between predicted level and actual performance level on test.

A mean value of 0 indicates that, on average, the students actually performed around the same level they self-reported or predicted for that learning target on the test. For example, the mean value of -0.05 indicates that, on average, students actually performed around the same level they predicted for learning target 9_1. A negative mean value indicates that, on average, the students actually performed lower than the level self-reported or predicted. For example, the mean value of -1.15 indicates that, on average, students actually performed lower than predicted for learning target 8_4. A positive mean value indicates that, on average, the students actually performed higher than the level self-reported or predicted.

Table 4.8 shows descriptive statistics for self-reported change and predicted change by unit.

Table 4.8

Descriptive Statistics for Self-Reported Change and Predicted Change by Unit

Unit	Mean Self-Reported Change	SD Self-Reported Change	Mean Predicted Change	SD Predicted Change
7	0.15	0.63	-0.31	0.55
8	-0.20	0.58	-0.75	0.64
9	0.31	0.47	-0.26	0.41
All	0.09	0.60	-0.44	0.59

Note. *Self-reported change* is the difference between self-reported level and actual performance level on test; *predicted change* is the difference between predicted level and actual performance level on test.

For Unit 7, the self-reported change mean of 0.15 indicates that, on average, students actually performed just higher than the mean level at which they self-reported. The predicted change mean of -0.31 indicates that, on average, students actually performed just lower than the level at which they predicted for that learning target on the test. Self-reported ratings (at what level does the student think she is right now?) during the class before the test were closer to the actual performance on the test than predicted scores (at what level does the student expect to be when taking the test during the next class?).

For Unit 8, the self-reported mean of -0.20 indicates that, on average, students actually performed just lower than the mean level at which they self-reported. The predicted mean of -0.75 indicates that, on average, students actually performed almost one level lower than the level at which they predicted for that learning target on the test. Self-reported levels (at what level does the student think he is right now?) during the class before the test were closer to the actual performance on the test than predicted levels (at what level does the student expect to be when taking the test during the next class?).

For Unit 9, the self-reported mean of 0.31 indicates that, on average, students actually performed just higher than the level at which they self-reported. The predicted mean of -0.26 indicates that, on average, students actually performed just lower than the level at which they predicted for that learning target on the test. Students were better at self-reporting than predicting. By Unit 9, predicted ratings (at what level does the student expect to be when taking the test during the next class?) were closer to the actual performance on the test than predicted scores (where is the student during the class period before the test?).

A paired t-test was conducted to compare Unit 7 self-reported change ($M=0.15$, $SD=0.63$) and predicted change ($M=-0.31$, $SD=0.55$) conditions; $t(40)=6.83$, $p < 0.0001$. A paired t-test was conducted to compare Unit 8 self-reported change ($M=-0.20$, $SD=0.58$) and predicted change ($M=-0.75$, $SD=0.64$) conditions; $t(40)=8.89$, $p < 0.0001$. A paired t-test was conducted to compare Unit 9 self-reported change ($M=0.31$, $SD=0.47$) and predicted change (M=-0.26, SD=0.41) conditions; $t(80)=5.87$, $p < 0.0001$. A paired t-test was conducted to compare all self-reported change (M=0.09, SD=0.60) and predicted change (M=-0.44, SD=0.59) conditions; $t(122)=14.6$, $p < 0.0001$.

For each unit individually and for all units together, the difference in predicted change and self-reported change was statistically significant. The null hypothesis is rejected. On average, student self-reported levels were closer to actual performance. Students overshot their predicted level by about one-half level.

Question 2

Are there interventions that improve student predictions for how they expect to perform on a test?

Question 2.1

Do worked examples have any effect on how close student predicted level is to actual performance level?

H_0: For students who received worked examples, the mean difference in actual performance level and student predicted level is equal to the mean difference for students who did not receive worked examples.

For Units 8 and 9, the teacher provided example problems of what each learning target looks like at each level along with the worked solutions (see Appendix H.) The predicted ratings were analyzed using a one-way ANOVA with statistical significance set at an alpha level of 0.05 to measure the influence of the independent variable, unit number, on the dependent variable, predicted change (see Table 4.9).

Table 4.9

One-Way Analysis of Variance of Predicted Change by Unit

Source	***df***	***SS***	***MS***	***F***	***p***
Between groups	2	5.92	2.96	10.12	0.000087
Within groups	120	35.08	0.29		
Total	122	41.00			

Note. *Predicted change* is the difference between predicted level and actual performance level on test.

Since $p < .01$, pairs of groups were analyzed using a Tukey-Kramer HSD Post-Hoc Test, indicating statistical significance both for Test 7 vs Test 8 and also Test 8 vs Test 9 (see Table 4.10).

Table 4.10

Tukey-Kramer HSD Comparison for Predicted Change by Unit

			95% CI	
Comparisons A vs B	Mean Grade Difference (A–B)	Std. Error	Lower Bound	Upper Bound
Test 7 vs Test 8	0.44*	0.17	0.15	0.72
Test 8 vs Test 9	-0.49*	0.06	0.21	0.77

Note. *Predicted change* is the difference between predicted level and actual performance level on test.
$^{*}p < .01$

For Unit 7, the predicted change mean of -0.31 indicates that, on average, students actually performed just lower than the level they predicted. For Unit 8, the predicted change mean of -0.75 indicates that, on average, students actually performed almost one level lower than the level they predicted. For Unit 9, the predicted change mean of -0.26 indicates that, on average, students actually performed just lower than the level they predicted. The closer the predicted change is to 0 indicates, the closer actual performance was to the student prediction. Actual performance was closer to student predictions on Unit 7 when compared to Unit 8, and on Unit 9 when compared to Unit 8, but there was no significant difference on Unit 7 when compared to Unit 9. Test results indicate a failure to reject the null hypothesis.

Question 2.2

Do worked examples and an emphasis on teaching students the importance of metacognition have any effect on how close student predicted level is to actual performance level?

H_0: For students who received worked examples and a metacognitive treatment, the mean difference in actual performance level and student predicted level is equal to the mean difference for students who did not receive worked examples and a metacognitive treatment.

All students received worked examples for Unit 8 and Unit 9. In addition, one class, section B2, received the metacognitive treatment for Unit 8. An ANOVA comparison on predicted change on Unit 8 for students who received the metacognitive treatment versus those who did not showed no statistical significance ($p = 0.116$).

All students received the metacognitive treatment for Unit 9, which was a second dose for the group who received the treatment in Unit 8. An ANOVA comparison on predicted change on Unit 9 for students who received the metacognitive treatment in both Unit 8 and Unit 9 versus those who did not showed no statistical significance ($p = 0.168$).

Instead of only comparing students within individual units, the researcher compared all predicted change results where students received the metacognitive treatment to all predicted change results where students did not receive the metacognitive treatment. All students for Unit 9 and section B2 for unit 8 received the metacognitive treatment. All remaining results, which included all students for Unit 7 and sections A4 and B3 for Unit 8, did not receive the metacognitive treatment (see Table 4.11).

Table 4.11

Results of t-test and Descriptive Statistics for Predicted Change by Worked Examples and Metacognitive Treatment

No			Yes			95% CI for Mean Difference	t	df
M	SD	n	M	SD	n			
-0.52	0.64	66	-0.34	0.49	57	-0.18, 0.21	-1.78*	121

Note: *predicted change* is the difference between predicted level and actual performance level on test.
* p < .05

A one-tailed t-test indicates statistical significance between students who received the metacognitive treatment and those who did not. The null hypothesis is rejected. Students who received the worked examples and a metacognitive treatment predicted closer to actual performance when compared to students who did not receive the worked examples and metacognitive treatment.

Question 2.3

Is there a difference between engineering and non-engineering students on how close student predicted level is to actual performance level?

H_0: For students who are in engineering, the mean difference in actual performance level and student predicted level is equal to the mean difference for non-engineering students.

Engineering students have used learning targets not only in math but also in engineering. A two-tailed t-test comparison for predicted change on Unit 7 for students who were in engineering classes versus those who were not showed no statistical significance (p = 0.481). A two-tailed t-test comparison for predicted change on Unit 8 for students who were in engineering classes versus those who were not showed no statistical significance (p = 0.779). A two-tailed t-test comparison for predicted change on Unit 9 for students who were in engineering classes versus those who were not showed no statistical significance (p = 0.526). A two-tailed t-test comparison for predicted change for students who had received the worked examples and metacognitive treatment showed no statistical significance between engineering students and non-engineering students (p = 0.591). Test results indicate a failure to reject the null hypothesis.

Question 2.4

Do worked examples and metacognitive strategies have any effect on how close student predicted level is to actual performance level for subgroups of students, based on particular self-reported levels and predicted levels?

H_0: For students in subgroups of particular self-reported and predicted levels, the mean difference in actual performance level and student predicted level for those who received worked examples and a metacognitive treatment is equal to the mean difference for those who did not.

Subgroup Who Self-Reported Level 3 and Predicted Level 4

There were 615 self-reported and predicted ratings used in the study. 28% of those ratings were students who self-reported Level 3 and predicted Level 4. The researcher determined whether those students performed lower than the self-reported Level 3, performed at the reported Level 3, or performed at the predicted Level 4. A chi-square test of independence was calculated comparing the frequency of those who performed lower than the self-reported Level 3, performed at the self-reported Level 3, or performed at the predicted Level 4, for Unit 7 & Unit 8 to Unit 9 (see Table 4.12 and Figure 4.1).

Table 4.12

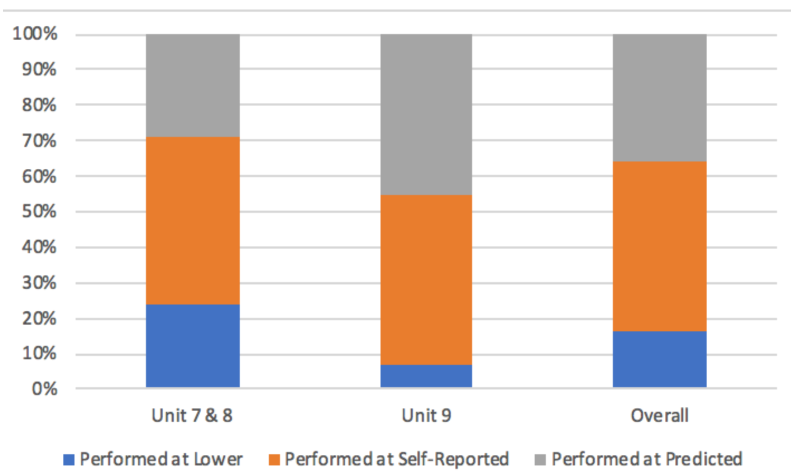
Actual Performance of Students Self-Reporting Level 3 and Predicting Level 4

Unit	Performed at Lower Level 1 or Level 2	Performed at Self-Reported Level 3	Performed at Predicted Level 4	Total
7 & 8	23 (24%)	46 (47%)	28 (29%)	97 (57%)
9	5 (7%)	35 (48%)	33 (45%)	73 (43%)
Total	28 (16%)	81 (48%)	61 (36%)	170 (100%)

Note. $\chi^2 = 10.29^*$, df = 2. Numbers in parentheses indicate column percentages.
*p = .005823

Figure 4.1

Test Results for Self-Reporting Level 3 and Predicting Level 4



Chi-square results show a statistically significant difference in self-reported ratings of 3 and predicted ratings of 4. The null hypothesis is rejected. For Unit 9, when all students received both the worked examples and metacognitive treatment, the chi-square test shows that 36% of students were expected to reach Level 4, but 45% of students actually reached it. But on Unit 7 and Unit 8, without both treatments, only 29% of students actually reached Level 4 when the chi-square test shows that 36% were expected to do so. On the Unit 9 test, the chi-square test shows that 16% of students were expected to perform lower than Level 3, but only 7% of students actually performed lower. For Unit 7 and Unit 8, when students did not receive the worked examples and metacognitive treatment, the chi-square test shows that only 16% of students were expected to perform lower than Level 3, but, in fact, 24% of students did perform lower than Level 3.

Subgroup Who Self-Reported Level 2 and Predicted Level 3

There were 615 self-reported and predicted ratings used in the study. 21% of those ratings were students who self-reported Level 2 and predicted Level 3. The researcher determined whether those students performed lower than the self-reported Level 2, performed at the self-reported Level 2, performed at the predicted Level 3, or performed at Level 4, which was higher than predicted. A chi-square test of independence was calculated comparing the frequency of those who performed students performed lower than the self-reported Level 2, performed at the self-reported Level 2, performed at the predicted Level 3, or performed higher than predicted at Level 4, for Unit 7 & Unit 8 to Unit 9 (see Table 4.13 and Figure 4.2).

Table 4.13

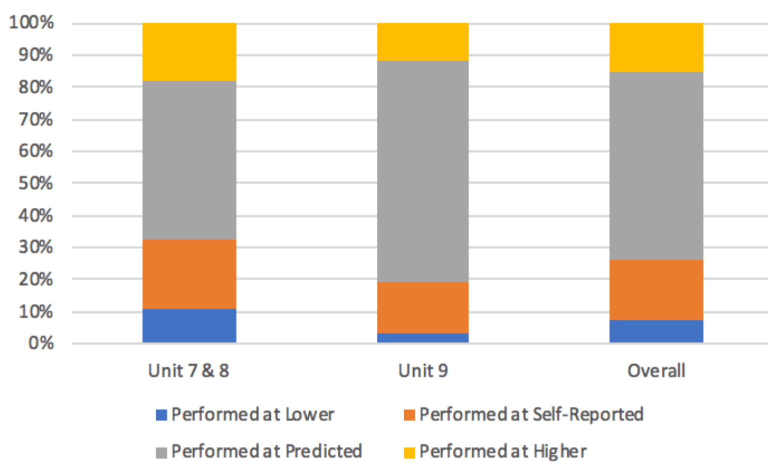
Actual Performance of Students Self-Reporting Level 2 and Predicting Level 3

Unit	Performed Lower Level 1	Performed at Self-Reported Level 2	Performed at Predicted Level 3	Performed Higher Level 4	Total
7 & 8	8 (11%)	15 (21%)	36 (50%)	13 (18%)	72 (55%)
9	2 (3%)	9 (16%)	40 (69%)	7 (12%)	58 (45%)
Total	10 (8%)	24 (18%)	76 (58%)	20 (15%)	130 (100%)

Note. $\chi^2 = 5.67^*$, df = 3. Numbers in parentheses indicate column percentages.
$^*p = .1289$

Figure 4.2

Test Results for Self-Reporting Level 2 and Predicting Level 3



Even though a higher percentage of students performed at their predicted Level 3 or performed higher than predicted at Level 4 during Unit 9, when students had the worked examples and metacognitive treatment, chi-square results show no statistical significance for students who self-reported Level 2 and predicted Level 3 between those who received treatments and those who did not. Test results indicate a failure to reject the null hypothesis.

The researcher elected not to examine more closely the ten ratings that self-reported Level 1 and predicted Level 2 or Level 3, since they comprised less than 2% of all ratings. Eight of those ratings were made by the same two students.

Subgroup Who Self-Reported Level 2 or Level 3 and Predicted the Same Level

There were 615 self-reported and predicted ratings used in the study. 26% of those ratings were students who self-reported Level 2 or Level 3 and predicted the same level. For each unit test, the researcher determined whether those students performed lower than the self-reported level, performed at the self-reported level (which was equivalent to performing at the predicted level), or performed at a higher level). A chi-square test of independence was calculated comparing the frequency of those who performed lower than the self-reported level, performed at the self-reported level (which was the same as the predicited level), or performed at a higher level, for Unit 7 & Unit 8 to Unit 9 (see Table 4.14 and Figure 4.3).

Table 4.14

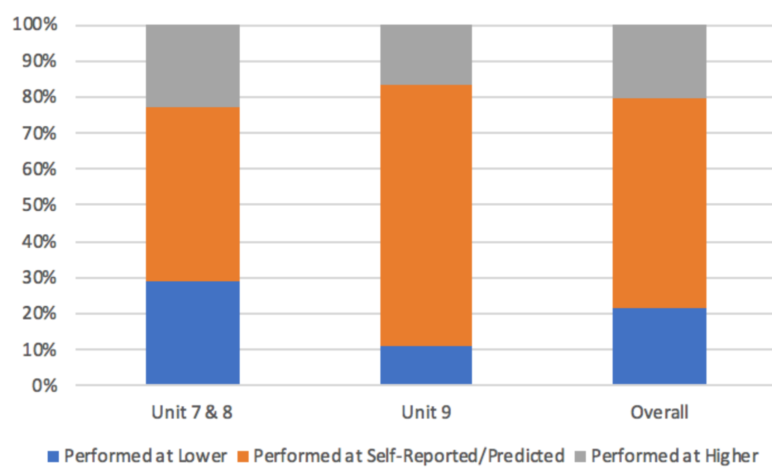
Actual Performance of Students Self-Reporting Level 2 or Level 3 and Predicting the Same Level

Unit	Performed at Lower Level	Performed at Self-Reported/Predicted Level	Performed at Higher Level	Total
7 & 8	27 (29%)	44 (48%)	21 (23%)	92 (59%)
9	7 (11%)	47 (72%)	11 (17%)	65 (41%)
Total	34 (22%)	91 (58%)	32 (20%)	157 (100%)

Note. χ^2 = 10.66*, df = 3. Numbers in parentheses indicate column percentages.
*p = .004843

Figure 4.3

Test Results for Self-Reporting Level 2 or Level 3 and Predicting the Same Level



Chi-square results show a statistically significant difference in results for self-reported ratings of Level 2 or Level 3 and predicted ratings of the same level. The null hypothesis is rejected. While 29% of students who did not receive the treatments performed at a level lower than self-reported or predicted, the chi-square test shows that only 22% were expected to do so. While only 11% of students who did receive the treatments performed at a level lower than self-reported or predicted, the chi-square test shows that 22% were expected to do so.

There were only 3 ratings for students who self-reported Level 1 and predicted the same level. The researcher elected not to further analyze those ratings because they comprised less than 1% of all ratings.

Subgroup Who Self-Reported Level 4 and Predicted the Same Level

There were 615 self-reported and predicted ratings used in the study. 20% of those ratings were students who self-reported Level 2 or Level 3 and predicted the same level. For each unit test, the researcher determined whether those students performed lower than the reported level, performed at the reported level (which was equivalent to performing at the predicted level), or performed at a higher level. A chi-square test of independence was calculated comparing the frequency of those who performed lower than the self-reported level, performed at the self-reported level, or performed at a higher level, for Unit 7 & Unit 8 to Unit 9 (see Table 4.14 and Figure 4.3).

Table 4.15

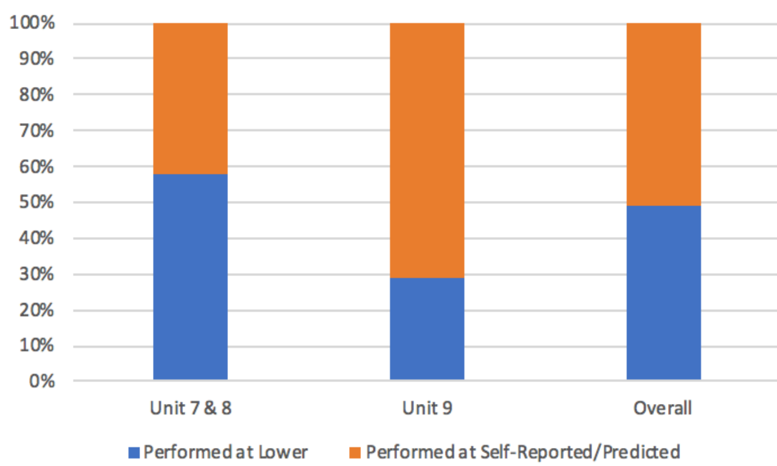
Actual Performance of Students Self-Reporting Level 4 and Predicting the Same Level

Unit	Performed at Lower Level	Performed at Self-Reported/Predicted Level 4	Total
7 & 8	49 (58%)	35 (42%)	84 (69%)
9	11 (29%)	27 (71%)	38 (31%)
Total	60 (49%)	62 (51%)	122 (100%)

Note. $\chi^2 = 9.04^*$, df = 1. Numbers in parentheses indicate column percentages.
$^*p = .002642$

Figure 4.4

Test Results for Self-Reporting Level 4 and Predicting the Same Level



Chi-square results show a statistically significant difference in results for self-reported ratings of Level 4 and predicted ratings of the same level. The null hypothesis is rejected. While 58% of students who did not receive the treatments performed at a level lower than self-reported or predicted, the chi-square test shows that only 49% were expected to do so. While only 29% of students who did receive the treatments performed at a level lower than self-reported or predicted, the chi-square test shows that 50% were expected to do so. Additionally, while 71% of students who did receive the treatments reached the predicted level, the chi-square test shows that only 50% were expected to do so.

SURVEY RESULTS

Question 3

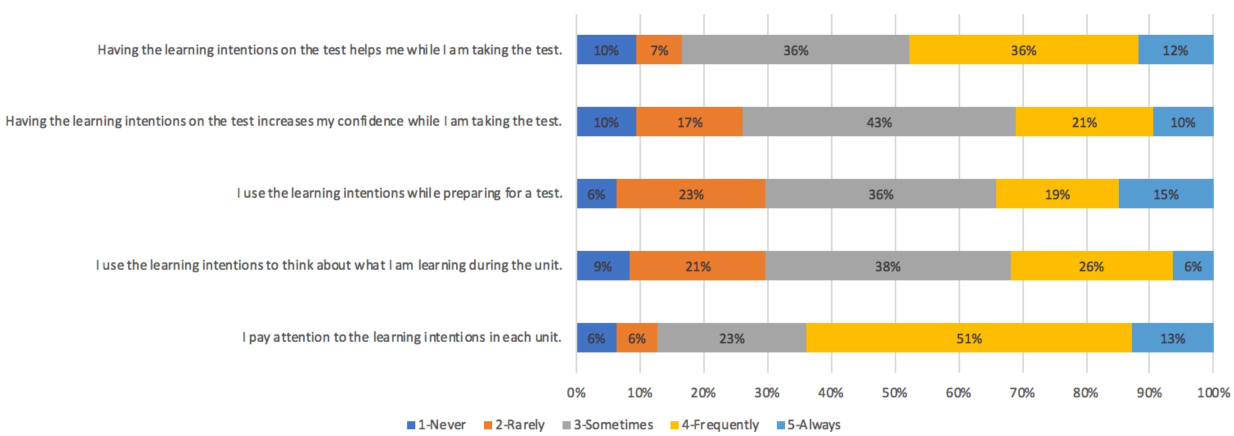
What are student perceptions around using learning targets to inform student progress in learning?

Of the 65 students who agreed to participate in the research study, 47 responded to a Google Form survey to share how they used learning targets and whether rating their progress and/or the worked examples were helpful in their learning (see Appendix K).

Student responses to Likert Scale questions around their perceptions on using learning targets are included in Figure 4.5.

Figure 4.5

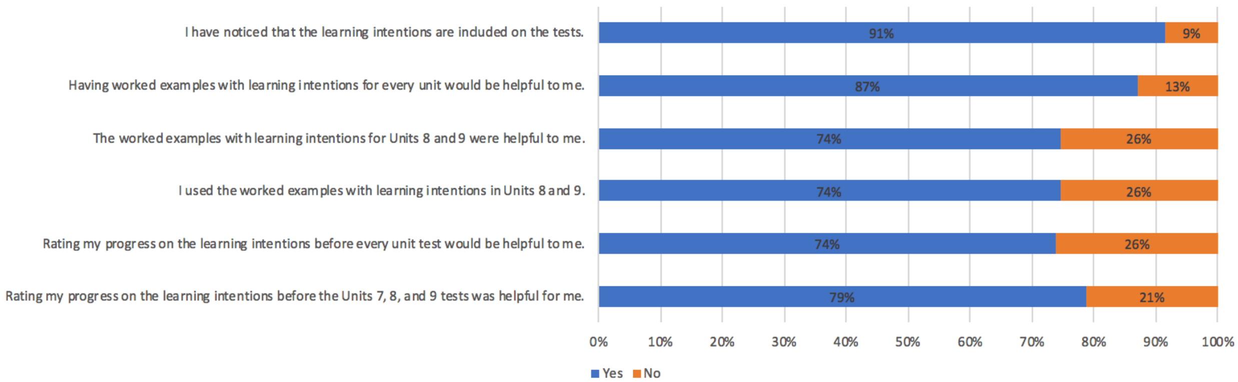
Student perceptions on Using Learning Targets, Likert Scale Questions



Student responses to yes or no questions around their perceptions on using learning targets are included in Figure 4.6.

Figure 4.6

Student perceptions on Using Learning Targets, Yes/No Questions



The learning targets are included on each test in Ms. Baird's precalculus class (see Appendix F). When students were asked how they use the learning targets while they testing, 92% of students use them in some way – to know what kind of problems will be in the upcoming section, to know which skills to use for the problems in the section, to know what the goal of the section is. One student noted that the learning targets make it more clear what the teacher is looking for in each section. Another noted that the learning targets are a reminder to the student that she has an understanding of what they learned during class.

When asked, "what might help you in your learning?" over half of the students acknowledged that studying and practicing would be helpful. Some completely contradicted each other in their needs: more group work, more lecture, more individual assistance from the teacher. A few students wrote specifically about learning targets. One student said he should study more to realize which skill needs attention and then learn more about that skill. Another suggested that teaching the lessons in the order of the learning targets would be helpful. Another student said that having the learning targets categorized on the test was helpful but wanted more clarity around which learning target was the focus of which lesson. One student suggested that studying strategies for solving problems corresponding to each learning target would help in her understanding of the material. One student noted that it would be helpful to know how to improve his skills for each section after a quiz. See Appendix L for complete survey responses to the two open-ended questions.

INTERVIEW RESULTS

Question 4

What are teacher perceptions around using learning targets to inform student progress in learning?

The researcher interviewed Ms. Baird by phone after collecting all student data to find out her thoughts on the research study and to see what aspects, if any, she might continue during another semester, class, or school year (see Appendix M). She shared anecdotal evidence around students rating their progress towards learning targets, noting that many students discussed their ratings with each other and said, “I really need to look at this before next time [test day].” Students not only had the realization that they were not where they needed to be but also discussed what they needed to do to get there. In particular, she noticed that several students rated themselves as Level 3 but wanted to be Level 4. They ended up getting Level 4 on the test, so they either went home and studied what they needed to know or they had not given themselves credit for what they already knew.

Ms. Baird posted the worked examples for Unit 8 in Canvas, the learning management system for the class. She mentioned to the students that they were available, but she did not emphasize their importance in preparing for the unit test. When students worked on their test corrections for Unit 8 in class after the test, she suggested that they pull up the worked examples and use them as they corrected their tests. For Unit 9, several students printed out the worked examples and used them in class each day. A few students asked questions about the worked examples during zero block. Some students used the worked examples while they were self-reporting and predicting their learning target levels. She noticed that the worked examples helped some students who did not otherwise know where to start to learn what they needed to know.

Ms. Baird emphasized the importance of metacognition with one class during Unit 8 and with all classes during Unit 9. She and other members of the mathematics department often ask students to think about where they are in their learning, but she noticed that self-reporting and predicting their learning target levels made student thinking more specific. The ratings pinpointed for students where they were and where they wanted to be and helped them realize that they still had time to do something about their rating. Ms. Baird overheard students asking each other where they were and where they wanted to be.

Ms. Baird plans to continue asking students to rate their progress towards learning targets, and she believes that starting out with Unit 1 will help students become accustomed to the practice and take it more seriously. She noted that writing leveled worked examples for each unit takes a lot of time, but she thinks that the time is worth it. In precalculus, she already has worked examples for Units 8 and 9, and so she plans to write them for other units next year.

One of the Algebra 1 teachers who works with Ms. Baird mentioned that her students' grades were not great, and so Ms. Baird suggested that she consider having students rate themselves to give them time and space to reflect on their learning and think about improving.

SUMMARY

This chapter reported the results of this mixed methods study, seeking insight on whether students' actual performance levels on test day are closer to the student predicted levels or closer to students' self-reported levels for a learning target and whether treatments such as worked examples and an emphasis on metacognition improve the predictions. The next chapter will summarize the results, consider what conclusions can be made and why, consider limitations of the study, and make suggestions about further research on this topic.

CHAPTER FIVE: DISCUSSION

Too often, in classrooms everywhere, students do not know how to respond when they are asked, “What are you learning about today in class?” Too often, in classrooms everywhere, teachers are offended by students who ask, “Is this going to be on the test?” Establishing and sharing learning goals and targets with students can alleviate some of the tension that comes between students and teachers and the aforementioned questions, but teachers and students often do not know where to start.

This research study sought to determine how well students predict their expected success for learning targets on a test. Self-reporting progress towards learning targets and setting an expectation for success has an effect size of 1.44, one of the highest effect sizes on student achievement (Hattie, Fisher, & Fray, 2017). The teacher in the research study asked students to self-report (at what level does the student think she is right now?) and predict (at what level does the student expect to be when taking the test during the next class?) on each learning target as Level 1-beginning, Level 2-progressing, Level 3-proficient, or Level 4-exceptional the class period before they take a test (see Appendix J).

When students know what the learning target is, they can compare where they think they are to where the learning target suggests they should be. When they are not where they should be yet, the incongruous progress spurs students to take action on their learning. When students know how they will know when they reach the learning target, they are better able to monitor their progress towards meeting it (Hattie, Fisher, & Fray, 2017). In order to realize the 1.44 effect size from self-reported grades/student expectations, teachers must ensure that students not only know what the learning target is but also how to reach the learning target.

The study hypothesized that treatments such as worked examples and an emphasis on teaching students the importance of metacognition not only help students know what the learning target is but also how to reach it, thus having a positive effect on student success predicting their expected success on a learning target, and, in fact, confirmed that worked examples and metacognitive strategies do contribute to how well students predict their expected success. Through questions for a student Google form and a teacher interview, the researcher also sought to determine student and teacher perceptions around using learning targets to inform student progress in learning. In considering how well students predicted the level at which they expected to perform for each learning target and what treatments might improve predicted success, a series of related questions was examined.

1. Are the students' actual performance levels on test day closer to the student predicted levels or closer to the students' self-reported levels (where they think they are on the day before the test)?

   H_0: The mean difference in actual performance level and student predicted level is equal to the mean difference in actual performance level and the self-reported level (where they think they are on the day before the test).

2. Are there interventions that improve student predictions for how they expect to perform on a test?

2.1 Do worked examples have any effect on how close student predicted level is to actual performance level?

H_0: For students who received worked examples, the mean difference in actual performance level and student predicted level is equal to the mean difference for students who did not receive worked examples.

2.2 Do worked examples and an emphasis on teaching students the importance of metacognition have any effect on how close student predicted level is to actual performance level?

H_0: For students who received worked examples and a metacognitive treatment, the mean difference in actual performance level and student predicted level is equal to the mean difference for students who did not receive worked examples and a metacognitive treatment.

2.3 Is there a difference between engineering and non-engineering students on how close student predicted level is to actual performance level?

H_0: For students who are in engineering, the mean difference in actual performance level and student predicted level is equal to the mean difference for non-engineering students.

2.4 Do worked examples and metacognitive strategies have any effect on how close student predicted level is to actual performance level for subgroups of students, based on particular self-reported levels and predicted levels?

H_0: For students in subgroups of particular self-reported and predicted levels, the mean difference in actual performance level and student predicted level for those who received worked examples and a metacognitive treatment is equal to the mean difference for those who did not.

3. What are student perceptions around using learning targets to inform student progress in learning?
4. What are teacher perceptions around using learning targets to inform student progress in learning?

CONCLUSIONS

The study confirms the hypothesis that treatments such as worked examples and metacognitive treatment can have a positive impact on student success predicting their progress towards a learning target.

Question 1

Are the students' actual performance levels on test day closer to the student predicted levels or closer to the students' self-reported levels (where they think they are on the day before the test)?

Hattie suggests that students know how they are going to perform on a test. When given the opportunity to self-report their performance level on a learning target, students set safe expectations. (Hattie, May 2012). The students in this study performed as Hattie suggests. Students self-reported (at what level does the student think he is right now?) and predicted (at what level does the student expect to be when taking the test during the next class?) their level for each learning target on the day before the test. The mean of all self-reported change for students in this study is 0.09, which indicates that, on average, students actually performed around the same level that they self-reported. The mean of all predicted change for students in this study is -0.44, which indicates that, on average, students actually performed at about one-half of a level lower than they predicted (see Table 4.8). Self-reported change is closer to 0 without performing lower than reported.

The predicted change shows that students expected to improve their progress towards meeting the learning targets. Did the students know how to change? Teachers should provide students clear indications of what it means to meet a learning target so that students will know how to improve (Hattie, Fisher, & Frey, 2017, p. 57).

Question 2

Are there interventions that improve student predictions for how they expect to perform on a test?

The researcher considered next whether providing students with worked examples might improve their predictions.

Question 2.1

Do worked examples have any effect on how close student predicted level is to actual performance level?

Teachers can help students better understand learning targets by sharing with students how the learning target will be assessed. Sharing example test problems is an ideal way to improve student understanding of the learning target. Sharing a novice worked example alongside a proficient worked example can also illuminate student understanding of the learning target (Popham, 2008).

For Units 8 and 9, the teacher provided example problems of what each learning target looks like at each level along with the worked solutions (see Appendix H). Actual performance was closer to student predictions on Unit 7 when compared to Unit 8, and on Unit 9 when compared to Unit 8, but there was no significant difference on Unit 7 when compared to Unit 9. For Unit 8, Ms. Baird distributed the worked examples via Canvas, the class learning management system. She alerted students at the beginning of the unit that worked examples were posted, but she did not overtly encourage students to use the worked examples. She did not notice many students take advantage of using the worked examples throughout Unit 8 to better understand the learning targets

When students received their Unit 8 tests back to correct them, Ms. Baird encouraged students to use the worked examples. Students engaged in self-explaining the steps in the worked examples as they compared the examples to the missed problems on the test and corrected the missed problems. At the end of Unit 8, students saw the advantage of using the worked examples when correcting the Unit 8 test, which could explain why there was statistical significance between predicted change on Unit 9 when compared to Unit 8, but it does not explain why there was no significant difference in predicted change from Unit 7 to Unit 9 and why the difference in predicted change from Unit 7 to Unit 8 was reversed. The researcher showed earlier that the three tests were not statistically different (see Tables 4.5 and 4.6), but Ms. Baird was on professional leave away from class more than one day during Unit 8, which could explain the anomaly of results for Unit 8.

Worked examples have been shown to improve student learning, but this research study does not show definitively that worked examples improve student success predicting their actual test performance. It could be that students need to be more deliberately taught how to use worked examples and not just provided worked examples for them to improve student predictions. Is there an intervention that might work alongside providing worked examples to positively affect student success predicting their success on a test?

Question 2.2

Do worked examples and an emphasis on teaching students the importance of metacognition have any effect on how close student predicted level is to actual performance level?

All students received worked examples for Unit 8 and Unit 9. One class, section B2, received the metacognitive treatment for Unit 8, and all students received the metacognitive treatment for Unit 9. Students who received the worked examples and a metacognitive treatment predicted closer to actual performance (about one-third of a level lower than actual performance) when compared to students who did not receive the worked examples and metacognitive treatment (more than one-half of a level lower than actual performance).

Establishing a norm in the classroom for all learners to share why they are thinking what they are thinking about a problem builds the habit of reflective learning for students, which increases the tendency for students to think about when something does not make sense and take time to figure out why. Some students will more naturally think about their learning than other students (Hattie, Fisher, & Frey, 2017). Teachers need to purposefully teach metacognitive strategies to the class and provide deliberate opportunities for reflecting on learning so that all students can advantageously use metacognitive strategies to improve learning (Hattie, Fisher, & Frey, 2017).

As shown in this research study, learning with worked examples is more effective when students are encouraged to self-explain the steps in the problem. Teachers are integral to training students how to self-explain (Renkl, 2014). When the teacher models the use of metacognitive strategies and discusses the strategies with students as they learn to use them, students eventually use the strategies themselves without being prompted by the teacher (Bransford, Brown, & Cocking, 2001).

Question 2.3

Is there a difference between engineering and non-engineering students on how close student predicted level is to actual performance level?

Engineering students have used learning targets not only in math but also in engineering. Just like in Ms. Baird's precalculus classes, engineering teachers clarify and share learning targets with students and include learning targets on the assessment, connected to the assessment items. Engineering students had more extensive experience using learning targets, and so it seems that they would out-predict their peers who were not in engineering classes. However, the engineering students did not out-predict their peers. The interventions used in their precalculus class–self-reporting the level they think they are and then predicting the level of success they expect to be on a test, worked examples, and metacognitive strategies–superseded any previous effect that using learning targets in multiple classes might have had.

Question 2.4

Do worked examples and metacognitive strategies have any effect on how close student predicted level is to actual performance level for subgroups of students, based on particular self-reported levels and predicted levels?

During the teacher interview, Ms. Baird reported anecdotally that several students rated themselves as Level 3 but wanted to be Level 4. Her observation was that they ended up getting Level 4 on the test, so they either went home and studied what they needed to know or they had not given themselves credit for what they already knew. In fact, the students were more likely to reach their predicted Level 4 on Unit 9, when they had both the worked examples and metacognitive treatment. Students were more likely to perform lower than their self-reported Level 3 on Unit 7 and Unit 8, when they did not have both treatments, and less likely to perform lower than their self-reported Level 3 on Unit 9, which they did have both treatments (see Figure 4.1). As Ms. Baird noted, it could be that these students did not give themselves credit for what they knew when they self-reported their level, but the statistical significance of what happened in Unit 9 when compared to Unit 7 and Unit 8 indicates that the worked examples and metacognitive treatments students made a difference for students who wanted to perform at a Level 4-exceptional on the test.

When students are not where they should be yet, the incongruous progress spurs students to take action on their learning. When students know how they will know when they reach the learning target, they are better able to monitor their progress towards meeting it (Hattie, Fisher, & Fray, 2017). The positive results for this group of students raise the question of why they were better able to reach their predicted level than other groups of students. These students were not satisfied with Level 3-proficient. They wanted to be Level 4-exceptional. It could be that the metacognitive treatment spurred this group to reflect on what they did not know and take action to do something about to improve their learning. It could be that the Level 4 worked examples provided just enough of a challenge for this group to work a little harder to better understand the learning target.

There was no statistical significance in self-reported ratings of 2 and predicted ratings of 3 for students who received the worked examples and metacognitive treatment (see Table 4.13 and Figure 4.2), which raises several questions. Did these students try to make use of the worked examples, but did not know how? How many of them sought out extra help from the teacher or other students? Wiliam calls out "activating learners as instructional resources for each other" and "activating learners as owners of their learning" two of his five key strategies of formative assessment (2011, p. 2). What additional interventions improve success for students who self-reported Level 2 and predicted Level 3?

Of the students who self-reported ratings of Level 2 or Level 3 and predicted ratings of the same level, students who received the worked examples and metacognitive treatment were less likely to score lower than self-reported and predicted. Those who did not receive the worked examples and metacognitive treatment were more likely to score lower than self-reported and predicted (see Table 4.14 and Figure 4). When given the opportunity to self-report their progress towards a learning target, students set safe expectations (Hattie, May 2012). Assuming Hattie's assertion, it appears that the worked examples and metacognitive treatment played a role in ensuring that the students met or exceeded that safe level, rather than falling below the safe level.

Students were more likely to reach their self-reported and predicted Level 4 on Unit 9, when they had both the worked examples and metacognitive treatment. It appears that the worked examples and metacognitive treatment played a role in ensuring that the students who self-reported and predicted Level 4 actually performed at that level. Students will have a better idea of what they are to learn when learning targets are embedded within learning progressions (Popham, 2008). It could be, more specifically, that these students had a better idea that they had reached Level 4-exceptional because of the progression of worked examples from levels 1 through 4.

Question 3

What are student perceptions around using learning targets to inform student progress in learning?

"The learning target articulates for students what they are to learn and at the same time provides insight as to how students will be assessed" (Kanold & Larson, 2012, p. 49). Over half of the students reported that they frequently or always pay attention to the learning targets in each unit (see Figure 4.5).

What is going to be on the test should not be a surprise to students. Learning targets should inform teachers what content-aligned items to put on the test and should inform students what content-aligned items will be on the test. Almost all students have noticed that the learning targets are included on the test, and about half reported that having the learning targets on the test frequently or always helps them while they are taking the test (see Figure 4.5).

Teachers can help students better understand learning targets by sharing with students how the learning target will be assessed. Sharing example test problems is an ideal way to improve student understanding of the learning target. Sharing a novice worked example alongside a proficient worked example can also illuminate student understanding of the learning target (Popham, 2008). Ms. Baird shared leveled worked examples for each learning target during Unit 8 and Unit 9 (see Appendix H).

For Unit 8, Ms. Baird posted the leveled worked examples through Canvas, the class learning management system, but she did not talk with students about how the leveled worked examples might be helpful to them in their learning. She reported during the teacher interview that she did not think many students used them for Unit 8. However, when students worked on correcting the Unit 8 test, she encouraged students to use the worked examples. That encouragement and a purposeful metacognitive treatment with students for Unit 9, caused more students to make use of the worked examples during Unit 9. By the end of the study, three-fourths of students reported that they used the worked examples in Units 8 and 9, and three-fourths of students reported that the worked examples were helpful in preparing for Units 8 and 9. Nine-tenths of students reported that having worked examples for all units would be helpful.

Self-reporting progress towards learning targets and setting an expectation for success has an effect size of 1.44, one of the highest effect sizes on student achievement. When students know what the learning target is, they can compare where they think they are to where the learning target suggests they should be. When they are not where they should be yet, the incongruous progress spurs students to take action on their learning. When students know how they will know when they reach the learning target, they are better able to monitor their progress towards meeting it (Hattie, Fisher, & Fray, 2017). While the study does not affirm that students made all of the connections that Hattie has between students knowing the learning target, rating success on it, and actions to take to improve success, over three-fourths of Ms. Baird's students reported that rating their progress on the learning targets before the Units 7, 8, and 9 tests was helpful, and three-fourths reported that rating their progress before every unit test would be helpful.

Question 4

What are teacher perceptions around using learning targets to inform student progress in learning?

Students will have a better idea of what they are to learn when learning targets are embedded within learning progressions. Learning progressions can provide information about the skills needed to reach a target as well as enrichment opportunities for those who have already reached the target (Popham, 2008). Writing learning progressions is challenging, time-consuming work for teachers (Popham, 2011). During the teacher interview, Ms. Baird echoed Popham's assertion that writing learning progressions is challenging and time-consuming. While Ms. Baird does not know that she will have the time to write a progression of leveled worked examples for each learning target in each unit that she teachers, she does plan to write more of them. In particular, Ms. Baird expressed concern about not being able to write a progression of leveled worked examples for on-level calculus, which will be a new prep for her. When she found out that the AP Calculus teacher has been using leveled worked examples, she thought that she might be able to start with that teacher's work and revise as needed for her own students. Not having to start the progression from scratch allayed her concern of the time and expertise needed to write the progression of leveled worked examples.

When given the opportunity to self-report their progress towards a learning target, students set safe expectations (Hattie, May 2012). Ms. Baird noted in her interview that having students predict their level afforded them the realization that they still had time to do something about how they would perform on the test. Self-reporting and predicting their levels for each learning target pinpointed for students not only where they were but also where they wanted to be.

Hattie goes on to say that teachers should not help students reach their potential level but help them go beyond what they think they can do (Hattie, May 2012). Building the habit of reflective learning for students increases the tendency for students to think about when something does not make sense and take time to figure out why (Hattie, Fisher, & Frey, 2017). Students become more interested in learning when they can gauge their progress towards meeting the learning goal and know what steps to take to improve (Sousa, 2015). Connecting leveled worked examples and metacognition not only provides students the opportunity to recognize their own potential but also know the steps to take to reach that potential.

LIMITATIONS

In this research study, students had the opportunity to self-report (at what level does the student think she is right now?) and predict (at what level does the student expect to be when taking the test during the next class?) on each learning target as Level 1-beginning, Level 2-progressing, Level 3-proficient, or Level 4-exceptional the class period before they take a test. A major limitation of this study is that no instrument was used to verify the accuracy of the student self-reported level; it was based only on each student's evaluation of where he thought he was at that time. The self-reported ratings are simply where students thought they were on the day before the test.

Are there students who think that it looks better to improve? How many students self-reported a lower level than he actually thought he was at the moment and predicted a higher level so that it appeared that he improved when he actually was at the higher level all along? Because the researcher did not collect data on student impressions for successful rating, and because the students self-reported ratings, some data could be skewed towards students seeming to improve a level when they were already at that level.

Students must partner with the teacher in reaching towards the learning target, and they can also help each other better understand learning targets. "It helps to make the students fully aware of the learning intentions and success criteria, of the value of deliberate practice, and of what to do when they do not know what to do" (Hattie, 2012, p. 111). Students become more interested in learning when they can gauge their progress towards meeting the learning goal and know what steps to take to improve (Sousa, 2015). In this research study, the focus was on whether providing the worked examples and metacognitive strategies improved predicted ratings. The teacher made the students aware of the learning intentions and success criteria. About half of the student responses to what might help in their learning asserted that more practice would help, so they are aware that deliberate practice is needed. However, no steps were taken to ensure that students know what to do when they do not know what to do. Ms. Baird had noted that the ratings pinpointed for students where they were and where they wanted to be and helped them realize that they still had time to do something about their rating. One student noted that knowing how to improve would be helpful. So it appears that the worked examples and metacognitive treatments made students aware that they needed to improve but without always know how to improve.

Many of the ratings for Unit 8 did not jive with the progression of ratings from Unit 7 to Unit 9. Ms. Baird was on professional leave for several days during that unit, which could have played a role in student success on that unit.

Half of the ratings collected from students during this research study were students who self-reported and predicted the same level, such as self-reporting Level 3 and predicting Level 3 or self-reporting Level 2 and predicting Level 2. The students seemed to already think they were where they wanted to be. Were these students satisfied with what they thought they already knew? Why did those who self-reported Level 2 predict that they would stay at Level 2 rather than trying to reach Level 3? Did they think it was too late to improve? Is this the group Hattie means when he says that teachers should not help students reach their prediction but exceed their prediction?

Almost half of the students self-reported at Level 2 and predicted Level 3 or self-reported at Level 3 and predicted Level 4. Did those students really know what it meant to be a Level 3 or Level 4? Or did they just think that they needed to get better? Because students self-reported their levels, the researcher has no way of knowing how accurate the self-reported level was.

RECOMMENDATIONS FOR FUTURE RESEARCH

"It helps to make the students fully aware of the learning intentions and success criteria, of the value of deliberate practice, and of what to do when they do not know what to do" (Hattie, 2012, p. 111). Students become more interested in learning when they can gauge their progress towards meeting the learning goal and know what steps to take to improve (Sousa, 2015). While this research study ensured that students were aware of the learning targets and the value of deliberate practice, there was no specific treatment that addressed possible actions students could take when they did not know what to do. Future research is needed to determine treatments that can help students know what steps to take to improve. For example, peer tutoring has an effect size of 0.55 (Hattie, 2012). Peer tutoring could be a treatment for students to purposefully utilize when they do not know how to improve their progress towards a learning target.

"The learning target articulates for students what they are to learn and at the same time provides insight as to how students will be assessed" (Kanold & Larson, 2012, p. 49). Further research is needed with a variety of student populations, such as those who have not used learning targets to think about where they are in their learning and those who have not had learning targets included on their test to realize that they provide insight into the assessment. Because the students in this research study had been using learning targets throughout the unit and on the test, they were farther on the path for recognizing their importance than students for whom learning targets are new.

In this study, students self-reported the level they thought they were the day before the test and predicted the level they expected to be when taking the test during the next class. No instrument was used to verify the accuracy of the student self-reported level; it was based only on each student's evaluation of where he thought he was at that time. Hattie asserts that teachers should not help students reach their predicted level but help them exceed their predicted level so that students do better than they thought they could and realize the power they have to improve their learning (Hattie, May 2012). In future research, using some sort of instrument to verify the accuracy of the students' self-reported levels can better inform teachers on ways to push students to gain the confidence that they need to believe that they have control over their learning.

One of the Algebra 1 teachers who works with Ms. Baird mentioned that her students' grades were not great, and so Ms. Baird suggested that she consider having students rate themselves to give them time and space to reflect on their learning and think about improving. Again, further research is needed with a variety of student populations in order to say with confidence that worked examples and metacognitive strategies improve how well all students predict their progress towards a learning target.

CONCLUSIONS

How often are teachers surprised to find out at the end of a learning episode that students have not actually learned? How often are teachers frustrated by students who ask, "Is this going to be on the test?"

This research study built on the importance of establishing learning goals and clarifying success criteria for students to find out how teachers might provide opportunities for *students* to use learning goals and success criteria formatively in order to know both what they have learned and what they still need to know. Self-reporting progress towards learning targets and setting an expectation for success has an effect size of 1.44, one of the highest effect sizes on student achievement. When students know what the learning target is, they can compare where they think they are to where the learning target suggests they should be. When they are not where they should be yet, the incongruous progress spurs students to take action on their learning. When students know how they will know when they reach the learning target, they are better able to monitor their progress towards meeting it (Hattie, Fisher, & Fray, 2017). Students were given the chance to self-report the level they thought they were the day before the test and predict the level at which they would perform on the test during the next class.

The study hypothesized that treatments such as worked examples and an emphasis on teaching students the importance of metacognition not only help students know what the learning target is but also how to reach it, thus having a positive effect on student success predicting the level at which they will perform on a learning target when they take a test, and, in fact, confirmed that worked examples and metacognitive strategies do contribute to student success when predicting the level at which they will perform on a learning target. When worked examples and metacognitive strategies are combined with the opportunity for students to predict the level at which they will perform on a learning target, not only will students know what is going to be on the test and how they are going to do on the test, they can use that information and work to improve their learning.

CHAPTER SIX: AN INFORMAL ADDENDUM

PURPOSE AND RESEARCH QUESTIONS

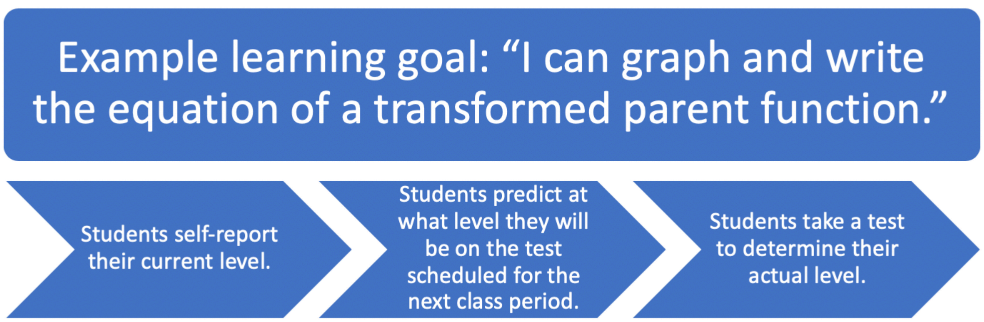
"It helps to make the students fully aware of the learning intentions and success criteria, of the value of deliberate practice, and of what to do when they do not know what to do" (Hattie, 2012, p. 111). Students become more interested in learning when they can gauge their progress towards meeting the learning goal and know what steps to take to improve (Sousa, 2015). Self-reporting progress towards learning targets and setting an expectation for success has an effect size of 1.44, one of the highest effect sizes on student achievement. When students know what the learning target is, they can compare where they think they are to where the learning target suggests they should be. When they are not where they should be yet, the incongruous progress spurs students to take action on their learning. When students know how they will know when they reach the learning target, they are better able to monitor their progress towards meeting it (Hattie, Fisher, & Fray, 2017).

While the original research study ensured that students were aware of the learning goals and the value of deliberate practice, there was no specific treatment that addressed possible actions students could take when they did not know what to do. Future research is needed to determine treatments that can help students know what steps to take to improve. For example, peer tutoring has an effect size of 0.55 (Hattie, 2012). Peer tutoring could be a treatment for students to purposefully utilize when they do not know how to improve their progress towards a learning goal.

In the original research study, students self-reported the level they thought they were the day before the test and predicted the level they expected to be when taking the test during the next class. Figure 6.1 shows the process that students completed for each learning target on the test.

Figure 6.1

Process Students Completed for Each Learning Target on the Test



Almost half of the students self-reported at Level 2 and predicted Level 3 or self-reported at Level 3 and predicted Level 4. Did those students really know what it meant to be a Level 3 or Level 4? Or did they just think that they needed to get better? A major limitation of the original study is that no instrument was used to verify the accuracy of the student self-reported level; it was based only on each student's evaluation of where he thought he was at that time. The self-reported ratings were simply where students thought they were on the day before the test.

Hattie asserts that teachers should not help students reach their predicted level but help them exceed their predicted level so that students do better than they thought they could and realize the power they have to improve their learning (Hattie, May 2012). To actually improve, students must do more than realize they can improve; they must take actions to improve. Revisiting the research study allowed for using an instrument to verify the students' current level before the test instead of relying on students' self-reported levels, giving students the opportunity to truly know where they needed to improve and giving the teacher better information on ways to push students to gain the confidence that they need to believe that they have control over their learning.

In the addendum to the study, a pre-test on the day before the test helped students determine their current learning level for each learning goal before predicting the learning level at which they planned to perform on test day. The teacher called the pre-test a "learning goal level quiz", as students were taking the pre-test to determine their current level on each of the learning goals, though students were not assigned a grade for the pre-test. Students were also asked questions around what they planned to do to reach their predicted level. After the test, students were asked what they actually did, whether it worked, and what they might do next time. Since the original research study confirmed the hypothesis that treatments such as worked examples and metacognitive treatment can have a positive impact on student success predicting their progress towards a learning goal, the teacher continued to use those treatments during the addendum. The following research questions were examined.

1. How does student performance on the pre-test compare to actual performance on the test?
2. How do student predictions compare to student performance?
3. When students know that they need to improve their progress towards a learning goal, how do they try to improve?

METHODOLOGY

This study also took place at Northwest Rankin High School, a suburban school in Rankin County School District near Jackson, Mississippi. The researcher partnered with a calculus teacher Ms. Dolf and her thiry-five AP Calculus students.

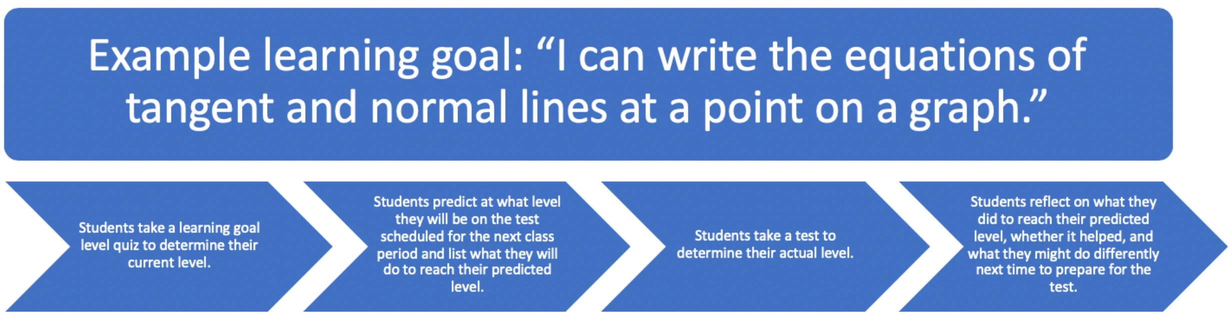
Ms. Dolf assessed the learning level of the students on the day before the test for five tests during the school year, utilizing a pre-test (see Appendix O) and a Google form with branching questions (see Appendix P). For each learning goal, the form starts first with a Level 3 question that branches to a Level 4 question if the student gets the Level 3 question correct and a Level 2 question if the student gets the Level 3 question incorrect. Students determine their current learning level for each learning goal based on the highest level question the student gets correct, with Level 1 corresponding to learning goals on which the student gets no correct response. Ms Dolf asked students not to guess on the pre-test and to select E for "I don't know how to do this problem" when needed to potentially limit the number of students who randomly selected the correct response.

Once students knew their current level, they had the opportunity to predict the level they expected to be when taking the test during the next class on each learning goal as Level 1-beginning, Level 2-progressing, Level 3-proficient, or Level 4-exceptional on the Unit Learning Goals Self-assessment Google form. Students were also given the opportunity to select what they planned to do to reach the predicted learning levels, such as using worked examples, studying with another student, getting help from a teacher or tutor, watching calculus videos, and/or reviewing class notes (see Appendix Q).

Ms. Dolf determined each student's actual learning level on each learning goal from their performance on the unit test. Students were given this information after the test, and when they looked over their tests with their classmates to make corrections, they were asked to reflect on what actions they took to reach their predicted level, whether it helped, and what they might do next time instead of or in addition to what they did this time on the Learning Goals Reflection Google form (see Appendix R). Figure 6.2 shows the process that students completed for each learning target on the test.

Figure 6.2

Process Students Completed for Each Learning Target on the Test During the Addendum



This strategy was employed over five units of study, Units 2, 3_1, 3_2, 4, and 5. Learning goals for all units are listed in Appendix S. Table 6.1 shows raw data for a few students for Unit 2. The raw data were used to determine how often students performed better on the pre-test than they did on the test and how often students performed at or exceeded their predicted level on the test when they predicted that they would perform higher than they did on the pre-test. For example, student 200 was a Level 1 on the first learning goal on the pre-test, predicted that she would be at a Level 3 on test day, and actually performed at Level 2 on the test. She was a Level 3 on the third learning goal on the pre-test, predicted that she would be at a Level 3 on test day, and actually performed at Level 4 on the test.

Table 6.1

Sample Student Data, Unit 2 Raw

Student Number	2_1 pre-test level	2_1 predicted level	2_1 actual test level	2_2 pre-test level	2_2 predicted level	2_2 actual test level	2_3 pre-test level	2_3 predicted level	2_3 actual test level	2_4 pre-test level	2_4 predicted level	2_4 actual test level
200	1	3	2	1	3	3	3	3	4	1	2	3
201	3	3	1	2	3	3	3	3	2	1	2	1
202	3	4	3	3	3	4	2	3	3	1	2	3

The mean of the pre-test levels, predicted levels, and actual test levels were calculated for each student for each unit and used to compare units (see Table 6.2). For example, student 200 had a mean level of 1.5 on the pre-test, predicted a mean level of 2.75, and actually performed at a mean level of 3 on the test. Individual students were removed from the total student count in any unit for which they were absent for the pre-test or if they opted out of predicting their learning levels on the test.

Table 6.2

Sample Student Data, Unit Means for Pre-test, Predicted, and Actual Test Levels

Student Number	Unit 2 pre-test mean	Unit 2 predicted mean	Unit 2 actual test mean	Unit 3_1 pre-test mean	Unit 3_1 predicted mean	Unit 3_1 actual test mean
200	1.5	2.75	3	~~1.83~~	—	~~2.83~~
201	2.25	2.75	1.75	2.17	2	2.17
202	2.25	3	3.25	~~2.67~~	—	~~2.83~~

Students were given the opportunity to select treatments that they planned to do while preparing for the test (see Table 6.3).

Table 6.3 *Sample Student Data, Student Reflection Before the Test*	
Student Number	What do you plan to do to reach your predicted learning levels?
200	Use the worked examples my teacher provided, Watch calculus videos, Review class notes
201	Use the worked examples my teacher provided, Study with another student, Watch calculus videos, Review class notes
202	Use the worked examples my teacher provided, Study with another student, Watch calculus videos

After the test, students were given the opportunity to reflect on what treatments they actually tried, whether the treatments helped, and what they might do the next time they prepare for a calculus test (see Table 6.4).

Table 6.4 *Sample Student Data, Student Reflection After the Test*			
Student Number	What did you do to reach your predicted learning levels? (select all that apply)	Did what you do helped? Explain.	What might you do next time instead of or in addition to what you did this time?
200	Use the worked examples my teacher provided, Watch calculus videos, Review class notes	I think it did help me do my better than i would have without it. I didn't do great on the test, but I think reviewing everything definitely helped me grasp the concepts better.	I would review like I did but I wish I would have gone back over definition of derivative problems because I struggled with those.
201			
202	Use the worked examples my teacher provided, Study with another student, Watch calculus videos	Yes because I was less confident on the objectives until I practiced the weekend	To do mathxl a week earlier

RESULTS

Question 1

How does student performance on the pre-test compare to actual performance on the test?

Table 6.5 shows the means of the pre-test level means and actual test level means for all students by unit. Students who were missing any learning goal levels in a unit were removed from the data for that unit. The difference between the actual test level mean and the pre-test level mean of 0.52 for Unit 3_2 indicates that, on average, students performed one-half level higher on the actual test than on the pre-test. The difference of -0.05 for Unit 4 indicates that, on average, students performed at about the same level on the actual test as on the pre-test.

Table 6.5

Pre-test and Actual Test Level Means of All Students by Unit

Unit	Number of students	Pre-test Level Mean	Actual Level Mean	Actual Level Mean – Pre-test Level Mean
2	33	1.87	2.10	0.23
3_1	21	2.23	2.75	0.52
3_2	19	2.27	2.64	0.37
4	20	2.11	2.06	-0.05
5	20	2.28	2.61	0.33
All	113	2.12	2.39	0.28

Table 6.6 drills down to each individual learning goal to show the percentage of students who had a higher level on the pre-test for that learning goal the day before the test than on the actual test. For Unit 3_1, 59% of students had a higher level on learning goal 3 on the pre-test the day before the test than they did on that learning goal on the actual test. For learning goal 3_1-5, 10% of students had a higher level on the pre-test than they did on

that learning goal on the actual test. For Unit 4, 36% of all learning goal ratings had a higher level on the pre-test than on the actual test.

Table 6.6

Student Data, Learning Goals with Student Performance Higher on Pre-test Than on Actual Test

Number of students								Mean %
	LG2_1	LG2_2	LG2_3	LG2_4				
33	43%	3%	31%	11%				22%
	LG3_1-1	LG3_1-2	LG3_1-3	LG3_1-4	LG3_1-5	LG3_1-6		
29	10%	17%	59%	14%	10%	21%		22%
	LG3_2-1	LG3_2-2	LG3_2-3	LG3_2-4	LG3_2-5			
28	14%	11%	21%	25%	36%			21%
	LG4-1	LG4-2	LG4-3	LG4-4a	LG4-4b	LG4-5		
32	25%	34%	---	---	25%	59%		36%
	LG5-1a	LG5-1b	LG5-2	LG5-3	LG5-4	LG5-5	LG5-6	
28	36%	25%	---	21%	---	18%	39%	28%

Question 2

How do student predictions compare to student performance?

Table 6.7 shows the means of the pre-test level means and predicted level means for all students by unit. Students who were missing any learning goal levels in a unit were removed from the data for that unit. The difference between the predicted level mean and the pre-test level mean of 0.77 for Unit 1 indicates that, on average, students predicted that they would score three-fourths of a level higher on the actual test than they did on the pre-test. The difference of 0.33 for Unit 3_2 indicates that, on average, students predicted that they would score one-third of a level higher on the actual test than they did on the pre-test.

Table 6.7

Pre-test and Predicted Level Means of All Students by Unit

Unit	Number of students	Pre-test Level Mean	Predicted Level Mean	Predicted Level Mean – Pre-test Level Mean
2	33	1.87	2.64	0.77
3_1	21	2.23	2.71	0.48
3_2	19	2.27	2.60	0.33
4	20	2.11	2.55	0.44
5	20	2.28	2.71	0.43
All	113	2.12	2.64	0.52

Table 6.8 shows the pre-test level and predicted level from the total number of learning goals rated in each unit. 18% of the predicted ratings for all students were lower than the level of the students on the pre-test.

Table 6.8

Comparison of Pre-test and Predicted Levels of Ratings for All Students

Comparison	Count
Predicted < Pre-test	97 (18%)
Predicted = Pre-test for Level 1 or Level 2	64 (12%)
Predicted = Pre-test for Level 3 or Level 4	99 (19%)
Predicted > Pre-test	273 (51%)

Table 6.9 shows data from the total number of learning goals rated in each unit, the number of those where students predicted they would perform higher on the test than they did on the pre-test, and the number of those where students actually did perform higher on the test than they did on the pre-test. For 63% of the ratings for Unit 2, students predicted they would perform higher on the test than they did on the pre-test; however, they only actually performed higher on the test than the pre-test for 37% of the Unit 2 ratings.

Table 6.9 *Student Prediction and/or Performance Greater Than Pre-test Level*				
Unit	Total Number of Learning Goals Rated	Predicted Level Greater Than Pre-test Level	Total Number of Learning Goals Rated	Actual Test Level Greater Than Pre-test Level
2	132	83 (63%)	140	52 (37%)
3_1	126	65 (52%)	174	90 (51%)
3_2	95	39 (41%)	140	53 (38%)
4	80	37 (46%)	128	39 (30%)
5	100	49 (49%)	140	65 (46%)
All	533	273 (51%)	722	299 (41%)

Table 6.10 shows the means of the predicted level means and actual level means for all students by unit. Students who were missing any learning goal levels in a unit were removed from the data for that unit. The difference between the actual level mean and the predicted level mean of 0.04 for Unit 3_1 and Unit 3_2 indicates that, on average, students performed at about the same level on the actual test as they predicted they would perform. The difference of -0.54 for Unit 2 indicates that, on average, students actually performed at about one-half level below on the actual test than they predicted they would perform.

Table 6.10 *Predicted and Actual Test Level Means of All Students by Unit*				
Unit	Number of Students	Predicted Level Mean	Actual Level Mean	Actual Level Mean – Predicted Level Mean
2	33	2.64	2.10	-0.54
3_1	21	2.71	2.75	0.04
3_2	19	2.60	2.64	0.04
4	20	2.55	2.06	-0.49
5	20	2.71	2.61	-0.10
All	113	2.64	2.39	-0.25

Table 6.11 shows how many students in each unit had an actual level mean on their test that was greater or equal to their predicted level mean. 60% of the students had an actual level mean on their Unit 3_2 test that was greater or equal to their predicted level mean.

Table 6.11

Student Comparison of Actual Test and Predicted Level Means by Unit

Unit	Number of Students	Actual Level Mean ≥ Predicted Level Mean
2	33	10 (30%)
3_1	21	10 (48%)
3_2	19	12 (60%)
4	20	5 (25%)
5	20	9 (45%)
All	113	46 (41%)

There was one student whose actual level mean was greater or equal to his predicted level mean on all five tests, and there was one student whose actual level mean was greater or equal to her predicted level mean on all four tests for which she had all of the data.

Question 3

When students know that they need to improve their progress towards a learning goal, how do they try to improve?

The Unit Learning Goals Self-assessment forms for all five units received 113 responses out of a possible 175 responses, a 65% student response rate, throughout the addendum study. The Learning Goals Reflection form received 88 responses, a 50% student response rate, throughout the addendum study. Table 6.12 displays the total number of student responses to the before question “What do you plan to do to reach your predicted learning levels? (select all that apply)” and the after question “What did you do to reach your predicted learning levels? (select all that apply)” During Unit 2, twenty-nine students planned to use the worked examples provided by the teacher and fourteen reported after the test that they did use the worked examples.

Table 6.12

Student Reflection Responses Before the Test/After the Test

Unit	Total number of student responses Before/after	Use the worked examples my teacher provided Before/after	Study with another student Before/after	Get help from a teacher or tutor Before/after	Watch calculus videos Before/after	Review class notes Before/after	Other Before/after
2	33/27	29/14	19/7	7/3	24/16	25/12	Do practice test /Absolutely nothing, various practice problems like Free Response Questions (FRQs)
3_1	21/23	18/15	21/6	3/1	17/11	11/13	Khan Academy, FRQs and Labs, Work on related PSPs, MathXL helps me a lot too / Khan Academy, Nothing, FRQ and lab
3_2	20/10	16/5	12/5	4/1	14/5	8/5	Nothing probably, FRQs and labs, Do my MathXL /MathXL
4	19/16	15/12	10/9	5/2	15/7	12/11	FRQs and general practice /FRQs
5	20/12	15/8	6/2	3/0	9/2	18/7	Do MathXL, FRQs, Make my own flash cards /MathXL, flash cards
All	113/88	93/54	68/29	22/7	79/41	74/48	

When students were asked after the test whether what they did to reach their predicted learning levels helped, 55% said *yes* with responses such as “I think it did help me do my [*sic*] better than i [*sic*] would have without it. I didn't do great on the test, but I think reviewing everything definitely helped me grasp the concepts better." and "I got help from a student, and it helped to have someone else's explanation as well." 20% said *somewhat* with responses such as "I think it was but I was tired so I didn't fully absorb the information." and "Maybe? I did a lot better on the test than I did on the practice." 20% said *no* with responses such as "No, I didn't have a good grasp on the subject to begin with, so the problems didn't help my understanding of this unit." and "I thought what I did helped but once I got to the test I realized my knowledge was not enough."

Half of the responses to "What might you do next time instead of or in addition to what you did this time?" had *more* in the response, such as "study more", "look over more examples", "work more problems." See Appendix T for complete results.

DISCUSSION

The addendum to this research study sought to determine how a pre-test might help students determine their current learning level for each learning goal before predicting the learning level at which they planned to perform on test day. The addendum also considered treatments that help students know what steps to take to improve their learning when they are not yet performing on a proficient level for a learning goal.

Question 1

How does student performance on the pre-test compare to actual performance on the test?

For Unit 4, on average, students performed at about the same level on the actual test as on the pre-test (see Table 6.5). This performance raised a red flag for Ms. Dolf and the researcher. Why didn't students perform better on the actual test than on the pre-test? It could be that students were satisfied with their level, it could be that students did not actually spend time preparing for the test as planned, it could be that the learning goal is particularly challenging, or it could be that the pre-test did not do a good job of assessing the student level before the test.

All of the items on the pre-test were multiple choice. Even though the Ms. Dolf included choice E for students to select if they did not know how to the problem, guessing or even having choices to eliminate could account for some of the greater success on the pre-test than on the actual test.

Using teacher- and researcher-created pre-tests raised some question of validity, so the researcher looked at student performance on each learning goal and found that over half of the students performed better on the pre-test for two learning goals (see Table 6.6). Those learning goals were not removed from this study, but if Ms. Dolf uses the pre-tests next year, she can use the data from this year to make a decision about how to proceed for next year. She might rewrite the items used on the pre-test to determine the level at which students are performing before the test, or if the learning goals are particularly challenging for students, she might consider teaching the content in a different way or providing a different type of practice for students than has been typical in years past. For Unit 4, 36% of the total learning goal ratings had a higher level on the pre-test than on the actual test. Ms. Dolf will need to look back at the Unit 4 pre-test in its entirety and compare it with the Unit 4 test to determine any discrepancies in assessing the level at which students are performing.

Question 2

How do student predictions compare to student performance?

Hattie suggests that students know how they are going to perform on a test. When given the opportunity to self-report their progress towards a learning target, students set safe expectations (May 2012). In the addendum to this research study, students had the opportunity to actually know the level at which they were performing on a learning goal before they predicted the level at which they planned to perform on the test. For Unit 1, on average, students predicted that they would score three-fourths of a level higher on the actual test than they did on the pre-test. For Unit 3_2, on average, students predicted that they would score one-third of a level higher on the actual test than they did on the pre-test. Unit 3_2 had more application problems than any other unit, which could account for lower student confidence on this unit. For all five units, on average, students predicted that they would score one-half of a level higher on the actual test than they did on the pre-test (see Table 6.7).

Hattie goes on to say that teachers should not help students reach their predicted level but help them exceed their predicted level (May 2012). Table 6.8 shows that 19% of students predicted they would perform on the test at a level lower than they performed on the pre-test. How might Ms. Dolf have specifically helped the students who, from the beginning, thought they would do worse on the test than they did on the pre-test? 31% of students predicted they would perform on the test at the same level that they performed on the pre-test, with 12% predicting they would stay at a Level 1 or Level 2 and 19% predicting they would stay at a Level 3 or Level 4.

51% of students predicted they would perform higher on the test than they performed on the pre-test. Just because students predicted they would perform higher on the actual test than they did on the pre-test does not mean they actually did perform higher. Table 6.9 shows that while students predicted they would perform higher on the actual test on about half of the learning goals they rated, they only actually exceeded that rating two-fifths of the time.

For Unit 3_1 and Unit 3_2, on average, students actually performed at about the same level on the actual test as they predicted they would (see Table 6.10). For all five units, on average, students actually performed at about one-fourth of a level below on the actual test than they predicted they would perform.

When comparing actual level means with their predicted level means, the actual level mean was greater or equal to the predicted level mean for only 41% of the 113 tests with complete data (see Table 6.11). It could be that taking the pre-test and reflecting on what actions they planned to take to reach their predicted learning levels made students over confident in not only what they could learn between the review day and the test day but also in how much time they would have to spend learning. Most of the students in the addendum to this study also participated in the original research study. This was their third math class in which they used and reflected on learning goals, and the second math class in which they predicted the level at which they expected to perform on the test. Students may have become too comfortable or even bored with the rating process, which may have skewed the results.

Question 3

When students know that they need to improve their progress towards a learning goal, how do they try to improve?

On the Unit Learning Goals Self-assessment before the test, over half of the 113 responses indicated that students planned to “use the worked examples my teacher provided”, “study with another student”, “watch calculus videos”, and “review class notes.” However, on the Learning Goals Reflection after the test, over half of the 88 responses indicated that students actually “used the worked examples my teacher provided” and “reviewed class notes” (see Table 6.12). According to Hattie, worked examples have an effect size of 0.57; in this study, most students said they took advantage of the worked examples that Ms. Dolf provided. Peer tutoring has an effect size of 0.55; in this study, students said that they planned to study with another student, but responses after the test did not indicate that many students took advantage of peer tutoring. Intelligent tutoring systems have an effect size of 0.48. MathXL, an online intelligent tutoring system, was not specifically mentioned to students in their reflection because Ms. Dolf requires that students complete MathXL practice assignments for the unit prior to review day. Even so, a few students mentioned MathXL as something they planned to do and did do to prepare for the test. Audio-visual methods have an effect size of 0.22, but interactive video methods have an effective size of 0.54 (Hattie, 2012). Students planned to watch calculus videos, and while there was not more specificity as to what type of videos they were watching, several students mentioned Khan Academy. Responses after the test indicated that not as many watched videos as had initially planned to do so.

By Unit 3_2, a few students requested to have the pre-test emailed to them several days before the review day so that they could do it before class and spend more time in class working on problems with each other. These students recognized the value of peer tutoring and knew that they did not have time outside of class to make that happen, and so they worked with Ms. Dolf to figure out both how to take advantage of the pre-test and peer tutoring during class. Some of the same students asked Ms. Dolf for the worked problems to the pre-test so that they could learn from their mistakes. She provided these to all students at the end of the day students took the pre-test.

Most striking in the student responses to "What might you do next time instead of or in addition to what you did this time?" is that over half of the student responses indicated that they had not done enough and should do *more* next time.

There were two students whose actual level mean was greater or equal to the predicted level mean on at least four of the tests. On the Learning Goals Reflection Form (see Appendix R), one of these students noted after the first test that "going over problems with another student helped me see their strategy at solving the problem." After the third test, the same student noted that she "did not understand L'Hopital's Rule or related rate problems before studying."

SCOPE AND LIMITATIONS

Only 35 students participated in the addendum to the research study, and participation waned as the school year progressed. For example, there was complete data for 33 students for Unit 2, but only 21 students had complete data for Unit 3_1. Ms. Dolf was out for the PSAT and a meeting, and several seniors were gone for a service project. Additionally, surveys were optional; after the first one, fewer students took the time to formally reflect on their learning. The rest of the units hovered around the same amount of participation with 19 students for Unit 3_2 and 20 students for Unit 4 and Unit 5.

Previously, half of the ratings collected from students during this research study were students who self-reported and predicted the same level, such as self-reporting Level 3 and predicting Level 3 or self-reporting Level 2 and predicting Level 2. The students seemed to already think they were where they wanted to be. Were these students satisfied with what they thought they already knew? Did they think it was too late to improve? Is this the group Hattie means when he says that teachers should not help students reach their prediction but exceed their prediction? Almost half of the students in the original research study self-reported at Level 2 and predicted Level 3 or self-reported at Level 3 and predicted Level 4. Did those students really know what it meant to be a Level 3 or Level 4? Or did they just think that they needed to get better? Because students self-reported their levels, the researcher had no way of knowing how accurate the self-reported level was. In the addendum to this study, the researcher had a more objective view of student improvement because of the pre-test that was used to pre-assess students' learning levels before they take the test. Unfortunately, the teacher and researcher realized that the pre-test was not always a great indicator of what students knew about a learning goal. Some learning goals cannot be reduced to a single assessment item for each level. For example, learning goal 4-4a is "I can use the Fundamental Theorem of Calculus" (see Appendix S). Using the Fundamental Theorem of Calculus with polynomial functions is not usually as challenging as using it with trigonometric or rational functions. Using the Fundamental Theorem of Calculus when *u*-substitution is required is more challenging than when *u*-substitution is not required. Reducing success on a learning goal to three assessment items to determine the level the student is performing prior to the test does not always work. Adding additional assessment items to the pre-test does not really work, either, as spending the whole of class time on the day before the test taking a long individual pre-test prevents students from learning together by talking and asking questions about mathematics.

All learning goals are not equally important, and they are not assessed at equal rates on the test. For example, for two learning goals in Unit 4 (4-2 and 4-3) and for two learning goals in Unit 5 (5-2 and 5-4), there was only one assessment item on the test, and it was not a Level 4 item. While some students predicted they would perform at a Level 4 on these learning goals on the test, there was no way to measure their performance beyond Level 3. Similarly, there was no way to measure their performance at Level 2, as missing the item resulted in a Level 1 for that learning goal on the test. The teacher and the researcher decided to remove these four learning goals from all calculations in the addendum. In the future, consideration should be given to whether a learning goal should be a learning goal if there is only one item on the test. It could be that the learning goal will be revisited in future units with additional types of functions, in which case it might be best to reserve mastery of the learning goal for the later unit only instead of including in both units. If the learning goal should be assessed in both units, the teacher should consider adding multiple items to the test so that student performance on the goal can be assessed beyond only Level 1 and Level 3.

The original research study followed three units in precalculus for which test grades from the current and previous precalculus teachers, Ms. Baird and Ms. Dolf, for the past three years showed no statistical difference between tests. The same cannot be said for the five units of calculus study in the addendum, and so no comparisons could be made from unit to unit to see whether students were improving over time in their predictions or how they planned to reach their predicted learning levels.

FUTURE RESEARCH

Writing a pre-test to determine the level at which students are performing with only three items per learning goal could be less challenging in an Algebra 1 class where students study a small number of function types than it is in an AP calculus class where students study concepts with multiple function types. Repeating this study in an Algebra 1 class could give insight into whether the pre-test works for some classes or topics but not others.

In the addendum to this study, while students predicted they would perform higher on the actual test on about half of the learning goals they rated, they only actually achieved or exceeded that rating two-fifths of the time (see Table 6.9). In AP Calculus, students constantly revisit content via different types of functions and applications. Repeating this study in a class where topics of study are less connected and more procedural could give more information about student confidence in their prediction and how teachers might support students to exceed their predicted level.

Research following students using learning goals and predicting their success over multiple classes and multiple school years could give insight into students' use of metacognitive strategies. If students are actively thinking about their learning in their math class because of actions initiated by the teacher, how might that look in a history class when the teacher is not initating a reflection on learning?

Finally, while the addendum gave the researcher more information about how students planned to reach their predicted learning levels when they had not done so yet, future research is needed to determine which treatments actually helped students improve. In particular, the teacher might start by interviewing the two students whose actual level mean was greater or equal to the predicted level mean on at least four of the tests to find out what helped them exceed their predictions.

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APPENDICES

APPENDIX A

Information Sheet

INFORMATION SHEET

Title: Leading Learners to Level Up

Investigator
Jennifer C. Wilson, M.S., NBCT
School of Education
320 Guyton Hall
The University of Mississippi
(601) 941-0029
jcwilso5@go.olemiss.edu

Advisor
Allan Bellman, Ph.D.
School of Education
320 Guyton Hall
The University of Mississippi
(662) 915-5309
abellman@olemiss.edu

Description
The purpose of this research project is to determine how self-rating progress on learning goals, worked examples, and metacognitive strategies might work together to improve student learning. We will ask students to rate their progress as beginning, progressing, proficient, or exceptional on unit learning goals for three units. In a final survey, we will ask students a few questions about how they used the ratings, worked examples, and metacognitive strategies during their learning. Students will not be asked to identify their name, and so the investigator will not be able to identify them.

Risks and Benefits
There are no anticipated risks to students from participating in the study. Students should not expect benefits from participating in this study. However, students might experience satisfaction from contributing to scientific knowledge. Also, participating in this research project may require students to think more about their progress towards each learning goal in the unit differently (e.g, more quantitatively) than they have done so before, which can lead to more deliberate study habits.

Confidentiality
All information in the study will be collected from students anonymously. It will not be possible for anyone, even the researchers, to associate a student with a student's responses.

Right to Withdraw
Students do not have to take part in this study and may stop participation at any time. If a student starts the study and decides that s/he does not want to finish, s/he can tell Ms. Wilson or Dr. Bellman in person, by letter, or by telephone (contact information listed above). Students may skip questions on the survey that they prefer not to answer.

IRB Approval
This study has been reviewed by The University of Mississippi's Institutional Review Board (IRB). If you have any questions, concerns, or reports regarding your rights as a participant of research, please contact the IRB at (662) 915-7482 or irb@olemiss.edu.

Statement of Consent
I have read and understand the above information. By completing the survey (students only) / interview (teacher only) I consent to participate in the study.

APPENDIX B

Recruitment Script

Recruitment Script (verbal, by teacher)

Ms. Wilson, who used to teach here, is a student at the University of Mississippi, and she has invited our precalculus class to participate in a research project to determine how self-rating progress on learning goals, worked examples, and metacognitive strategies might work together to improve your learning.

As a participant, you will be asked to complete four Google Form surveys. You will have time to complete the surveys during class, and so participation in the project will not require any of your time outside of class.

There are no anticipated risks from participating in the study. Nor should you expect benefits from participating in this study. However, you might experience satisfaction from contributing to scientific knowledge. Also, the potential for personal gain from participating in this research project is high, as it will likely require you to think more about your progress towards each learning goal in the unit more visibly than you have done so before, which can lead to more deliberate study habits not only in mathematics but also in other subjects.

You do not have to take part in this study and may stop participation at any time. Your participation is strictly voluntary and you are under no obligation to answer any questions on any of the surveys that you do not want to answer.

Do you have any questions now?
If you have questions later, please contact Ms. Wilson at jcwilso5@go.olemiss.edu.

If you would like to participate in this research study, please let me know.

APPENDIX C

Parental Consent

PARENTAL PERMISSION FOR STUDENT PARTICIPATION

Consent for Your Child to Participate in Research

Study Title: *Leading Learners to Level Up*

Investigator
Jennifer C. Wilson, M.S., NBCT
School of Education
320 Guyton Hall
The University of Mississippi
(601) 941-0029
jcwilso5@go.olemiss.edu

Faculty Sponsor
Allan Bellman, Ph.D.
School of Education
320 Guyton Hall
The University of Mississippi
(662) 915-5309
abellman@olemiss.edu

The purpose of this study

The purpose of this research project is to determine how self-rating progress on learning goals, worked examples, and metacognitive strategies might work together to improve student learning.

What your child will do for this study

1. The researchers will ask students to rate their progress as beginning, progressing, proficient, or exceptional on unit learning goals for each of three units.
2. In a final survey, the researchers will ask students a few questions about how they used the ratings, worked examples, and metacognitive strategies during their learning. Students will not be asked to identify themselves in any manner and thus their anonymity will be protected.

Time required for this study

The survey for rating student progress on unit learning goals will take less than 5 minutes each. The final survey will take students 5-8 minutes, for a total of about 30 minutes.

Possible risks from participation

There are no anticipated risks to students from participating in the study.

Benefits from participation

Students should not expect benefits from participating in this study. However, students might experience satisfaction from contributing to scientific knowledge. Also, the potential for personal gain from participating in this research project is high, as it will likely require students to think more about their progress towards each learning goal in the unit more visibly than they have done so before, which can lead to more deliberate study habits not only in mathematics but also in other subjects.

Confidentiality

All information in the study will be collected from your child anonymously. It will not be possible for anyone, even the researchers, to associate your child with your child's responses.

Right to Withdraw ***(Adapt language to your study)***

Students do not have to take part in this study and may stop participation at any time. If a student starts the study and decides that s/he does not want to finish, s/he can tell Ms. Wilson or Dr. Bellman in person, by letter, or by telephone (contact information listed above). Students may skip questions on the survey that they prefer not to answer.

IRB Approval

This study has been reviewed by The University of Mississippi's Institutional Review Board (IRB). The IRB has determined that this study fulfills the human research subject protections obligations required by state and federal law and University policies. If you have any questions or concerns regarding your rights or your child's rights as a research participant, please contact the IRB at (662) 915-7482 or irb@olemiss.edu.

Please ask the researcher if there is anything that is not clear or if you need more information. When all your questions have been answered, then decide if you want your child to be in the study or not.

Statement of Consent

I have read the above information. I have been given an unsigned form to complete. I have had an opportunity to ask questions, and I have received answers. I consent to allow my child to participate.

Furthermore, I also affirm that the experimenter explained the study to me and told me about the study's risks as well as my right and my child's right to refuse to participate and to withdraw, and that I am the parent/legal guardian of the child listed below.

Name of Parent/Legal Guardian

Name of Child

Date

CLICK HERE IF YOU, AS THE PARENT OR LEGAL GUARDIAN, PERMIT YOUR CHILD TO PARTICIPATE.

APPENDIX D

School District Consent

RANKIN COUNTY SCHOOL DISTRICT
GREAT TO BEST

Post Office Box 1359 • Brandon, MS 39043 • p 601.825.5590 • f 601.825.2618 • www.rcsd.ms

February 7, 2018

Ms. Jennifer Wilson
19 Lake Avenue
Black Mountain, NC 28711

RE: Research

Dear Ms. Wilson,

My team has reviewed your information regarding your research study, Leading Learners to Level Up. I am pleased to grant you permission to conduct your research study and survey at Northwest Rankin High School as outlined in the research. Participants **must** consent prior to study.

Best wishes in your educational endeavors.

Sincerely,

Sue Townsend

Sue Townsend, Ph.D.
Superintendent of Education
Rankin County School District

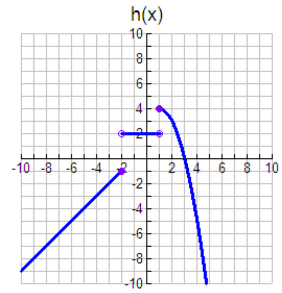
APPENDIX E

Precalculus Assessment Before

Unit 8 Piecewise, Composite, & Inverse Functions. No Calculator.
Sign and Pledge: I pledge that I am turning in my own work.

1. Given the graph of h(x).
a. Write a piecewise function for h(x).

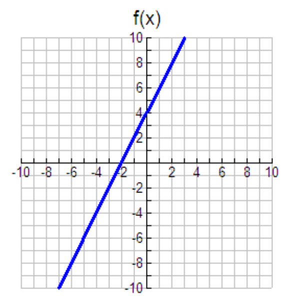
b. True or False: h(x) is constant on (-2,2).



2. Rewrite the following absolute value functions as piecewise functions.
a. $f(x)=|3x-4|+1$
b. $f(x)=|5-x|-3$

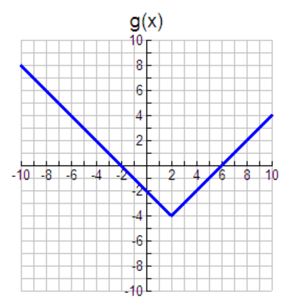
3. If possible, use the table below to evaluate the following.

x	j(x)	n(x)
-1	5	0
0	3	0.2
1	-2	-4
2	4	7



a. $(j\circ n)(-1)$
b. $(j-n)(2)$
c. $(n\circ j)(1)$

4. Use the graphs of f(x) and g(x) to evaluate the following.
a. $(f+g)(0)$
b. $(g\circ f)(-1)$
c. $(f\circ g)(1)$



5. Determine whether the following functions are one to one.
a. $f(x)=x^2+4$ b. $f(x)=2x^3-5$

6. If $f(x)=\dfrac{4x}{x-2}$ find $f^{-1}(x)$ and give its domain.

7. Find the value of each of the following if the given functions are as follows:

$f(x)=3x+4$ $\quad g(x)=\sqrt{x-5}$ $\quad h(x)=x^2-1$ $\quad k(x)=1-5x$

a. Domain of $\left(\frac{f}{k}\right)(x)$ b. $(h\circ f)(-3)$ c. $(g\circ h)(x)$

d. Domain of $(g\circ h)(x)$ e. $(h\circ g)(x)$ f. Domain of $(h\circ g)(x)$

8. Given $f(x)=px+r$.

a. What is $f^{-1}(x)$?

b. Complete the following table.

	slope	x-intercept	y-intercept
f(x)			
$f^{-1}(x)$			

c. Make a conjecture about the slopes of two linear functions that are inverses of each other.

d. Make a conjecture about the x- and y-intercepts of two linear functions that are inverses of each other. Will this be true for all functions and their inverses? Explain your reasoning.

9. a. Determine a function f(x) such that $f(x)=f^{-1}(x)\ \forall\, x$.

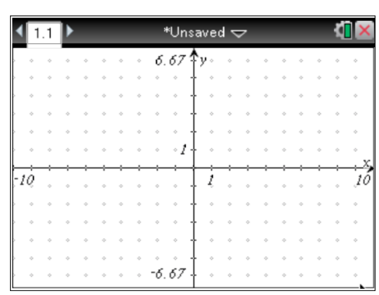
b. What must be true about a function that is its own inverse?

10. The difference quotient of a function f is given by $\frac{f(x+\Delta x)-f(x)}{\Delta x}$. Find the difference quotient for the function $f(x)=x^2-4x+1$. Simplify your answer.

11. Find the difference quotient $\frac{f(h+3)-f(3)}{h}$ for $f(x)=\frac{2}{x+1}$.

12. Given $f(x)=\sqrt{x+2}$ and $a=4$. $f'(4)$ is given by $\frac{f(x)-f(a)}{x-a}$. Find the difference quotient and rewrite it by rationalizing the numerator. Then evaluate $f'(4)$ by evaluating your rewritten difference quotient at $x=4$. You have found the slope of the line tangent to the graph of $f(x)=\sqrt{x+2}$ at $x=4$.

13. Given $k(x)=\begin{cases} 2x, & x<2 \\ |x-3|+1, & 2\le x<5 \\ 5, & x\ge 5 \end{cases}$.



a. Sketch a graph of k(x).

b. Evaluate the following: $k(0)$, $k(2)$, $k(4)$, $k(5)$, $k(8)$.

APPENDIX F

Precalculus Assessment After

Unit 8 Piecewise, Composite, & Inverse Functions **Name** ____________________________

No Calculator **Please circle your answers!**

I can perform various operations on of functions, including addition, subtraction, multiplication, division, and composition. I can determine the properties of these new functions.

1. If possible, use the table below to evaluate the following.

x	j(x)	n(x)
-1	5	0
0	3	0.2
1	-2	-4
2	4	7

a. $(j \circ n)(-1)$

b. $(j - n)(2)$

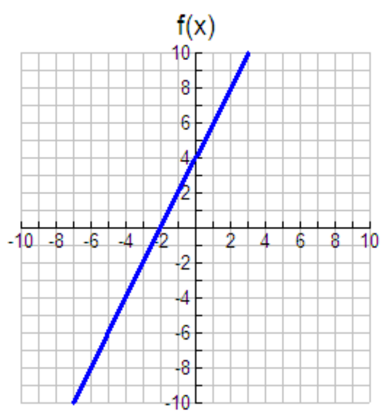
c. $(n \circ j)(1)$

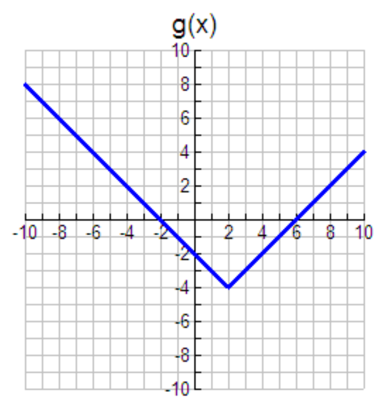
2. Use the graphs of f(x) and g(x) to evaluate the following.

a. $(f + g)(0)$

b. $(g \circ f)(-1)$

c. $(f \circ g)(1)$





3. Find the value of each of the following if the given functions are as follows:

$f(x) = 3x + 4$ $\quad g(x) = \sqrt{x - 5}$ $\quad h(x) = x^2 - 1$ $\quad k(x) = 1 - 5x$

a. Domain of $\left(\frac{f}{k}\right)(x)$

b. $(h \circ f)(-3)$

c. $(g \circ h)(x)$

d. Domain of $(g \circ h)(x)$

e. $(h \circ g)(x)$

f. Domain of $(h \circ g)(x)$

I can determine if a function is one-to-one and find the inverse of a function.

4. Determine whether the following functions are one to one.

a. $f(x)=x^2+4$

b. $f(x)=2x^3-5$

5. Given $f(x)=\dfrac{4x}{x-2}$ find

a. $f^{-1}(x)$

b. The domain of $f^{-1}(x)$

6. Given $f(x)=px+r$.

a. What is $f^{-1}(x)$?

b. Complete the table at the right.

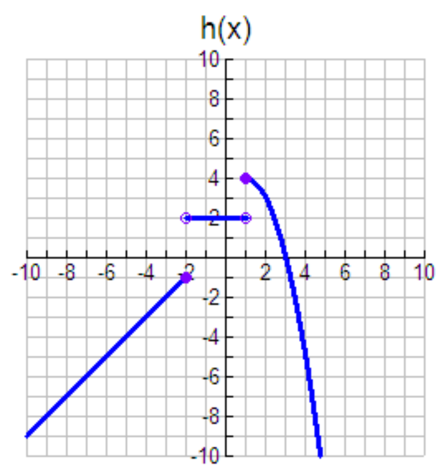
c. Make a conjecture about the slopes of two linear functions that are inverses of each other.

	slope	x-intercept	y-intercept
f(x)			
$f^{-1}(x)$			

d. Make a conjecture about the x- and y-intercepts of two linear functions that are inverses of each other. Will this be true for all functions and their inverses? Explain your reasoning.

I can graph, write equations for, and determine properties of piecewise functions including writing absolute value functions as piecewise functions.

7. Given the graph of h(x), write a piecewise function for h(x).



8. Rewrite the following absolute value functions as piecewise functions.

a. $f(x)=|3x-4|+1$

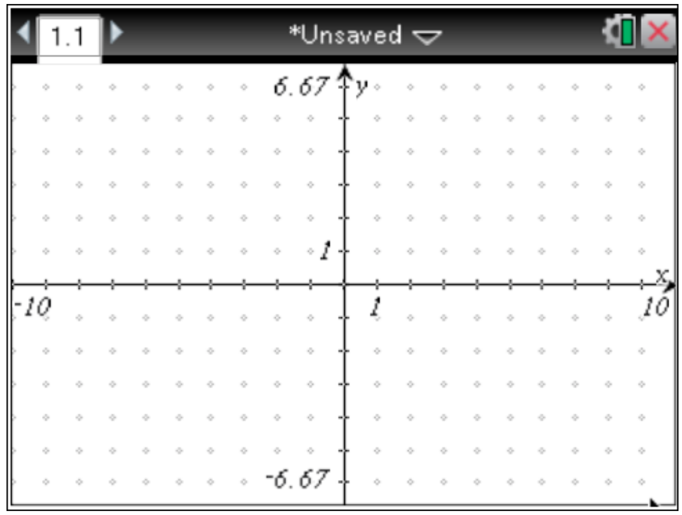
b. $f(x)=|5-x|-3$

9. Given $k(x)=\begin{cases} 2x, & x<2 \\ |x-3|+1, & 2\le x<5 \\ 5, & x\ge 5 \end{cases}$.

a. Sketch a graph of k(x).

b. Evaluate the following:

$k(0)$, $k(2)$, $k(4)$, $k(5)$, $k(8)$.



I can simplify the difference quotient of a polynomial, rational, or radical function.

10. The difference quotient of a function f is given by $\frac{f(x+\Delta x)-f(x)}{\Delta x}$. Find the difference quotient for the function $f(x)=x^2-4x+1$. Simplify your answer.

11. Find the difference quotient $\frac{f(h+3)-f(3)}{h}$ for $f(x)=\frac{2}{x+1}$. Simplify your answer.

12. Given $f(x)=\sqrt{x+2}$ and $a=4$. $f'(4)$ is given by $\dfrac{f(x)-f(a)}{x-a}$. Find the difference quotient and rewrite it by rationalizing the numerator. Then evaluate $f'(4)$ by evaluating your rewritten difference quotient at $x=4$.
You have found the slope of the line tangent to the graph of $f(x)=\sqrt{x+2}$ at $x=4$.

I can determine if a function is continuous. I can identify discontinuities as removable (point) or nonremovable (jump or asymptotic).

13. (Free Response Question) Consider the two piecewise defined functions, *f(x)* and *g(x)*, below to answer the following questions.

$$f(x)=\begin{cases} x^2+\dfrac{2}{3}x, & -9<x\le -3 \\ -2x+1, & -3<x<2 \\ x+3, & x>2 \end{cases} \qquad g(x)=\begin{cases} ax+3, x<-2 \\ x^2+2x, x\ge -2 \end{cases}$$

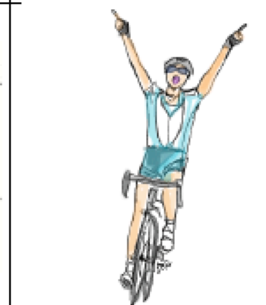
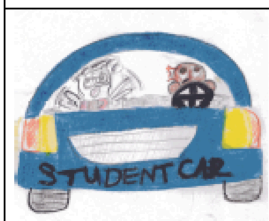
a. Find *f(-9), f(-3), f(7),* and the domain of *f(x).*

b. Does *f(x)* have a discontinuity at *x=-3*? If so, classify it. Justify your reason.

c. For what value(s) of *a* is the graph of *g(x)* continuous at *x=-2*?

APPENDIX G

Leveled Learning Progression Rating Example

Analogy	Level 1	Level 2	Level 3	Level 4
	Beginning	Progressing	Proficient	Exceptional
Swimming	I'm getting my feet wet.	I'm comfortable with support.	I'm confident with the process.	I'm ready for the deep end.
Biking	I need training wheels.	Training wheels off – but I still need help.	I can ride with no help.	I can ride with no hands.
				
Driving	I have a learner's permit.	I have an intermediate license.	I have a driver license.	I can compete with professional race car drivers.
				
Baseball	I am starting to understand the rules, but I still need help with the basics.	I understand the game, but I need a lot of practice to improve.	I know the game, and I am confident with my skills.	I have mastered the skills, and I am ready for the big league.

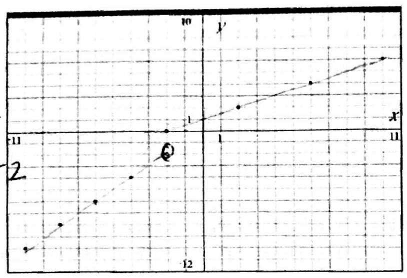
Unit 8 Learning Targets with Leveled Worked Examples

Unit 8 Worked Examples

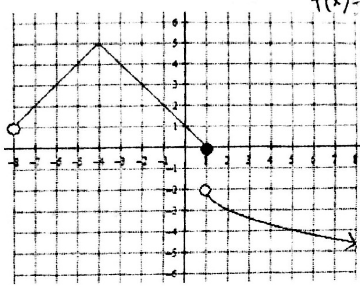
I can graph, write equations for, and determine properties of piecewise functions.

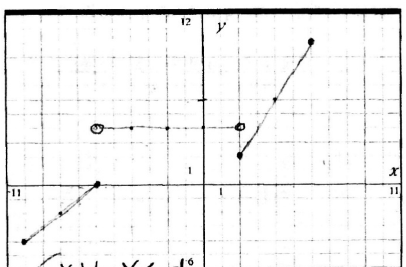
i. Write an equation for the following graphs of piecewise functions.

$f(x) = \begin{cases} x, & x < -2 \\ \frac{1}{2}x + 1, & x \geq -2 \end{cases}$

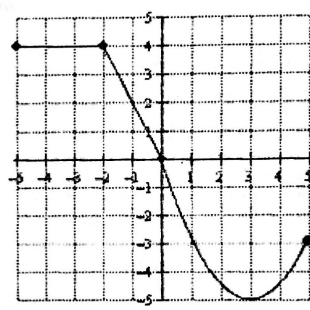


$f(x) = \begin{cases} -|x+4| + 5, & -8 < x \leq 1 \\ -\sqrt{x-1} - 2, & x > 1 \end{cases}$





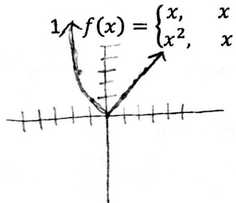
$f(x) = \begin{cases} x + 6, & x \leq -6 \\ 4, & -6 < x < 2 \\ 2x - 2, & 2 \leq x \leq 6 \end{cases}$



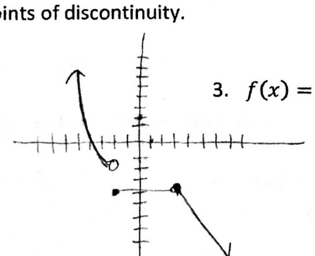
$f(x) = \begin{cases} 4, & -5 \leq x \leq -2 \\ -2x, & -2 \leq x \leq 0 \\ .5x^2 - 3x - .5, & 0 \leq x \leq 5 \end{cases}$

ii. Sketch the graph of the piecewise-defined function. (Try doing it without a calculator.) In each case, give any points of discontinuity.

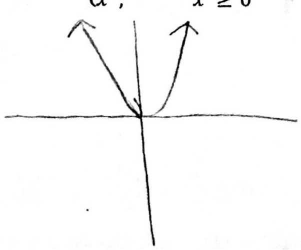
1. $f(x) = \begin{cases} x, & x \leq 0 \\ x^2, & x > 0 \end{cases}$



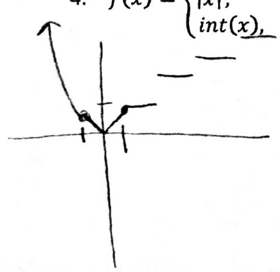
3. $f(x) = \begin{cases} x^2 - 6, & x < -2 \\ -4, & -2 \leq x < 3 \\ -2x + 2, & x \geq 3 \end{cases}$



2. $f(x) = \begin{cases} |x|, & x < 0 \\ x^2, & x \geq 0 \end{cases}$



4. $f(x) = \begin{cases} x^2, & x < -1 \\ |x|, & -1 \leq x < 1 \\ int(x), & x \geq 1 \end{cases}$



Unit 8 Worked Examples

I can rewrite absolute value functions as piecewise functions.

iii. Rewrite the following absolute value functions as piecewise functions.

1. $f(x) = |x|$

$f(x) = \begin{cases} x, & x \geq 0 \\ -x, & x < 0 \end{cases}$

2. $f(x) = |x| + 4$

$f(x) = \begin{cases} x+4, & x \geq 0 \\ -x+4, & x \leq 0 \end{cases}$

3. $f(x) = -|x-3| - 2$

$f(x) = \begin{cases} -(x-3)-2 \\ (x-3)-2 \end{cases} = \begin{cases} -x+1, & x \geq 3 \\ x-5, & x < 3 \end{cases}$

4. $f(x) = -2|x+3| + 1$

$f(x) = \begin{cases} -2(x+3)+1, & x \geq -3 \\ 2(x+3)+1, & x < -3 \end{cases} = \begin{cases} -2x-5, & x \geq -3 \\ 2x+7, & x < -3 \end{cases}$

I can perform various operations on of functions, including addition, subtraction, multiplication, division, and composition.

iv. Find *f+g*, *f-g*, and *fg* for the following functions.

1. $f(x) = 2x - 1; g(x) = x^2$

$(f+g)(x) = 2x-1+x^2$

$(f-g)(x) = 2x-1-x^2$

$(fg)(x) = (2x-1)(x^2) = 2x^3 - x^2$

2. $f(x) = (x-1)^2; g(x) = 3 - x$

$(f+g)(x) = x^2 - 3x + 4$

$(f-g)(x) = x^2 - x - 2$

$(fg)(x) = (x-1)^2(3-x) = -x^3 + 5x^2 - 7x + 3$

3. $f(x) = \sqrt{x}; g(x) = \sin x$

$(f+g)(x) = \sqrt{x} + \sin(x)$

$(f-g)(x) = \sqrt{x} - \sin(x)$

$(fg)(x) = \sqrt{x}\sin(x)$

4. $f(x) = \sqrt{x+5}; g(x) = |x+3|$

$(f+g)(x) = \sqrt{x+5} + |x+3|$

$(f-g)(x) = \sqrt{x+5} - |x+3|$

$(fg)(x) = \sqrt{x+5}\,|x+3|$

Find f/g for the following function

5. $f(x) = \sqrt{x+3}; g(x) = x^2$ $\quad \dfrac{\sqrt{x+3}}{x^2}$

v. Find $f(g(x))$ and $g(f(x))$ for the following functions

1. $f(x) = 3x + 2; g(x) = x - 1$

$f(g(x)) = 3(x-1) + 2 = 3x - 1$

$g(f(x)) = 3x + 2 - 1 = 3x + 1$

2. $f(x) = x^2 - 2; g(x) = \sqrt{x+1}$

$f(g(x)) = \sqrt{x+1}^2 - 2 = x - 1$

$g(f(x)) = \sqrt{x^2 - 2 + 1} = \sqrt{x^2 - 1}$

3. $f(x) = x^2; g(x) = \sqrt{1 - x^2}$

$f(g(x)) = \sqrt{1-x^2}^2 = 1 - x^2$

$g(f(x)) = \sqrt{1 - (x^2)^2} = \sqrt{1 - x^4}$

4. $f(x) = \frac{1}{2x}; g(x) = \frac{1}{3x}$

$f(g(x)) = \dfrac{1}{2\left(\frac{1}{3x}\right)} = \dfrac{3x}{2}$

$g(f(x)) = \dfrac{1}{3\left(\frac{1}{2x}\right)} = \dfrac{2x}{3}$

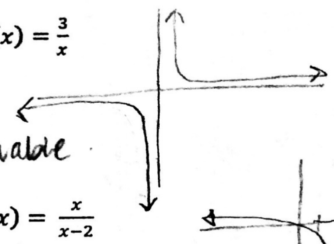
Unit 8 Worked Examples

I can determine if a function is continuous. I can identify discontinuities as removable (point) or nonremovable (jump or asymptotic). Exercise 21-24 (102)

vi. Graph the function and tell whether or not there is a point of discontinuity at x= 0. If there is a discontinuity, well whether it is removable or not removable.

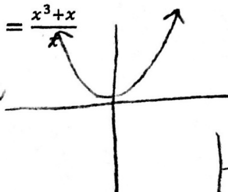
1. $g(x) = \frac{3}{x}$

Yes, non-removable

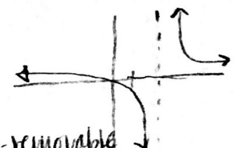


3. $h(x) = \frac{x^3+x}{x}$

Yes, removable

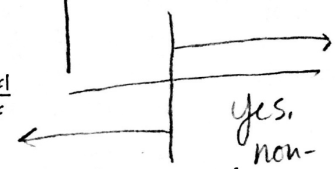


2. $g(x) = \frac{x}{x-2}$



Yes, non-removable

4. $f(x) = \frac{|x|}{x}$



yes, non-removable

I can determine properties of composite and inverse functions such as domain, range, and function values.

vii. Give the domain $f(g(x))$ for each function. (from sections v.).

1. $f(x) = 3x + 2; g(x) = x - 1$

Domain: $(-\infty, \infty)$

$f(g(x)) = 3(x-1)+2$

2. $f(x) = x^2 - 2; g(x) = \sqrt{x+1}$

Domain: $[-1, \infty)$

$f(g(x)) = \sqrt{x+1}^2 - 2$

3. $f(x) = x^2; g(x) = \sqrt{1-x^2}$

Domain: $[-1, 1]$

$f(g(x)) = \sqrt{1-x^2}^2$

4. $f(x) = \frac{1}{2x}; g(x) = \frac{1}{3x}$

$f(g(x)) = \frac{1}{2\left(\frac{1}{3x}\right)}$

Domain: $(-\infty, 0) \cup (0, \infty)$

viii. If $f(x) = \sqrt{25-x^2}$ and $g(x) = \sqrt{x}$, find $\left(\frac{f}{g}\right)(x)$ and give its domain.

$\left(\frac{f}{g}\right)(x) = \frac{\sqrt{25-x^2}}{\sqrt{x}} = \sqrt{\frac{25-x^2}{x}}$

$\frac{25-x^2}{x} \geq 0$

$x \neq 0$ b/c of denominator

D: $(-\infty, -5] \cup (0, 5]$

$+ \quad - \quad + \quad -$

$-5 \quad 0 \quad 5$

I can simplify the difference quotient of a polynomial, rational, or radical function.

11. The difference quotient of a function f is given by $\frac{f(x+\Delta x) - f(x)}{\Delta x}$. Find the difference quotient for the function $f(x) = \frac{3}{x}$. Simplify your answer.

$\frac{\frac{3}{x+\Delta x} - \frac{3}{x}}{\Delta x} = \frac{\frac{x}{x} \cdot \frac{3}{x+\Delta x} - \frac{3}{x} \cdot \frac{x+\Delta x}{x+\Delta x}}{\Delta x} = \frac{3x - 3x - 3\Delta x}{x(x+\Delta x)\Delta x} = \frac{-3\Delta x}{x(x+\Delta x)\Delta x}$

$= \frac{-3}{x(x+\Delta x)}$

12. Find the difference quotient $\frac{f(h+3) - f(3)}{h}$ for $f(x) = x^2 + 4x - 1$.

$\frac{(h+3)^2 + 4(h+3) - 1 - (9+12-1)}{h} = \frac{h^2 + 6h + 9 + 4h + 12 - 1 - 20}{h}$

$\frac{h^2 + 6h + 9 + 4h - 9}{h} = \frac{h^2 + 10h}{h} = \frac{h(h+10)}{h} = h + 10$

APPENDIX I

Assessment Instrument Quality-Evaluation Tool

Figure 1.16

Assessment Instrument Quality-Evaluation Tool

Assessment Indicators	Description of Level 1	Requirements of the Indicator Are Not Present	Limited Requirements of This Indicator Are Present	Substantially Meets the Requirements of the Indicator	Fully Achieves the Requirements of the Indicator	Description of Level 4
Identification and emphasis on essential learning standards (specific feedback to students)	Learning standards are unclear and absent from the assessment instrument. Too much attention is given to one target.	1	2	3	4	Learning standards are clear, included on the assessment, and connected to the assessment questions.
Visual presentation	Assessment instrument is sloppy, disorganized, difficult to read, and offers no room for work.	1	2	3	4	Assessment is neat, organized, easy to read, and well-spaced, with room for teacher feedback.
Balance of higher- and lower-level-cognitive-demand tasks	Emphasis is on procedural knowledge with minimal higher-level-cognitive-demand tasks for demonstration of understanding.	1	2	3	4	Test is rigor balanced with higher-level and lower-level-cognitive-demand tasks present.
Clarity of directions	Directions are missing and unclear. Directions are confusing for students.	1	2	3	4	Directions are appropriate and clear.
Variety of assessment task formats	Assessment contains only one type of questioning strategy, and no multiple choice or evidence of the Mathematical Practices. Calculator usage not clear.	1	2	3	4	Assessment includes a blend of assessment types and assesses Mathematical Practices modeling or use of tools. Calculator expectations clear.
Tasks and vocabulary (attending to precision)	Wording is vague or misleading. Vocabulary and precision of language are a struggle for student understanding and access.	1	2	3	4	Vocabulary is direct, fair, accessible, and clearly understood by students, and they are expected to attend to precision in response.
Time allotment	Few students can complete the assessment in the time allowed.	1	2	3	4	Test can be successfully completed in the time allowed.
Appropriate scoring rubric (points)	Scoring rubric is not evident or is inappropriate for the assessment tasks presented.	1	2	3	4	Scoring rubric is clearly stated and appropriate for each task or problem.

Source: Kanold, T. D. (Ed.), Kanold, T. D., & Larson, M. (2012). Common Core mathematics in a PLC at work, leader's guide. *Bloomington, IN: Solution Tree Press. (See p. 94.)*

APPENDIX J

Unit 7 Learning Targets Self-Assessment Form

Information

You do not have to participate in this survey. If you choose to participate, you do not have to answer any question that you would rather not answer, and you can exit the survey at any time.

1. **Research Number (the researcher will not be able to identify you by name throughout the study)**

I can graph and write the equation of a transformed parent function.

1: Beginning
2: Progressing
3: Proficient
4: Exceptional

2. **Current Level**
   Mark only one oval.

1	2	3	4
◯	◯	◯	◯

3. **Predicted Level for Test**
   Mark only one oval.

1	2	3	4
◯	◯	◯	◯

I can recognize transformations given a graph or equation.

1: Beginning
2: Progressing
3: Proficient
4: Exceptional

4. **Current Level**
   Mark only one oval.

1	2	3	4
◯	◯	◯	◯

5. **Predicted Level for Test**
Mark only one oval.

1	2	3	4
⬭	⬭	⬭	⬭

I can determine properties of a graph of function such as domain, range, extrema, increasing, decreasing, constant, intercepts, and symmetry.

1: Beginning
2: Progressing
3: Proficient
4: Exceptional

6. **Current Level**
Mark only one oval.

1	2	3	4
⬭	⬭	⬭	⬭

7. **Predicted Level for Test**
Mark only one oval.

1	2	3	4
⬭	⬭	⬭	⬭

I can write a function or graph with given properties or determine that such a function cannot exist and why.

1: Beginning
2: Progressing
3: Proficient
4: Exceptional

8. **Current Level**
Mark only one oval.

1	2	3	4
⬭	⬭	⬭	⬭

9. **Predicted Level for Test**
Mark only one oval.

1	2	3	4
⬭	⬭	⬭	⬭

APPENDIX K

Student Feedback on Learning Targets Form

Learning Intentions

You do not have to participate in this survey. If you choose to participate, you do not have to answer any question that you would rather not answer, and you can exit the survey at any time.

1. **I pay attention to the learning intentions in each unit. (5-Always, 4-Frequently, 3-Sometimes, 2-Rarely, 1-Never)**
   Mark only one oval.

	1	2	3	4	5	
Never	◯	◯	◯	◯	◯	Always

2. **I use the learning intentions to think about what I am learning during the unit. (5-Always, 4-Frequently, 3-Sometimes, 2-Rarely, 1-Never)**
   Mark only one oval.

	1	2	3	4	5	
Never	◯	◯	◯	◯	◯	Always

3. **I use the learning intentions while preparing for a test. (5-Always, 4-Frequently, 3-Sometimes, 2-Rarely, 1-Never)**
   Mark only one oval.

	1	2	3	4	5	
Never	◯	◯	◯	◯	◯	Always

4. **Rating my progress on the learning intentions before the Units 7, 8, and 9 tests was helpful for me.**
   Mark only one oval.

   ◯ Yes
   ◯ No

5. **Rating my progress on the learning intentions before every unit test would be helpful to me.**
   Mark only one oval.

   ◯ Yes
   ◯ No

6. **I used the worked examples with learning intentions in Units 8 and 9.**
   Mark only one oval.

   ◯ Yes
   ◯ No

7. **The worked examples with learning intentions for Units 8 and 9 were helpful to me.**
   Mark only one oval.

   - ( ) Yes
   - ( ) No

8. **Having worked examples with learning intentions for every unit would be helpful to me.**
   Mark only one oval.

   - ( ) Yes
   - ( ) No

9. **I have noticed that the learning intentions are included on the tests.**
   Mark only one oval.

   - ( ) Yes *Skip to question 10.*
   - ( ) No *Skip to question 13.*

Learning Intentions on the Test

10. **Having the learning intentions on the test increases my confidence while I am taking the test. (5-Always, 4-Frequently, 3-Sometimes, 2-Rarely, 1-Never)**
    Mark only one oval.

	1	2	3	4	5	
Never	( )	( )	( )	( )	( )	Always

11. **Having the learning intentions on the test helps me while I am taking the test. (5-Always, 4-Frequently, 3-Sometimes, 2-Rarely, 1-Never)**
    Mark only one oval.

	1	2	3	4	5	
Never	( )	( )	( )	( )	( )	Always

12. **How do you use the learning intentions while you are testing?**

13. **What might help you in your learning?**

APPENDIX L

Student Feedback on Learning Targets Responses to Open-Ended Questions

How do you use the learning intentions while you are testing?

- I think about them if I get stuck.
- I look at the learning intentions to further understand what is being asked in the question on the test.
- I use them to reaffirm I am solving the problems correctly and to the highest ability.
- I use them to analyze the problem and relate it back to real class experience and different practices!
- I honestly don't look at the intentions on the test. I go straight to the problems and assess them without thinking about the learning intentions.
- By knowing what I am looking for
- It allows me to know what I am looking for.
- They point me in a direction so I will know what is needed to work a problem.
- These help me understand the task of the math problem I am about to face while testing.
- The learning intentions gives me a sense of what to study for the test.
- I look at them to remember exactly what that problem is testing
- It helps me understand what I should know.
- To know what the goal of the section is.
- I use them on certain parts of the test in which when I need to use it.
- I set a goal for me to reach on the test
- I use it to do a quick review of all the stuff I should know.
- I never do
- I use them to understand what I am trying to figure out. I help them to realize what kind of answer I should have.
- to understand how to answer the problems
- As words on they page that give me a hint to what I should do.
- The learning intentions during the test are helpful because it allows a frame of reference on how to approach the problem(s) and which field of the unit it is about.
- It helps me to know what I know and what I do not know. It reminds me that I have an understanding of what we have learned
- I use them to determine how I will solve the problem given.
- I am able to think back to problems I worked out and use them as examples on the test.
- When reading the intentions, I get prepared for what problems I am about to do on the tests
- Seeing the intentions on the test helps to remind me of the specific types of problems I am about to have on my test.
- It helps me know what I should be trying to accomplish in each section of the test.
- It somewhat gives a way to know what I'm doing and narrowing down when I get to questions on what method I need to do and what will be best

- I read the learning intentions as a preview to what the questions in that section will be asking. I use the learning intentions to help me understand what I am doing ahead of time so I don't read a question and become confused as to what method I may need to use to solve it.
- I try to remember what they were so I know what steps I need to take the test in.
- I just use it to help me know which specific skills goes along with the test.
- I use them to solve my way to get the problem
- I don't.
- It helps me determine what I need to do in order to solve for the problem and get the correct answer
- The learning intentions make me think about what we have learned so far in the unit and make me calm down when I cannot figure out how to work a problem. Looking at the learning intentions helps me to remember which skills to use.
- They give an idea of the answer they're looking for.
- I remembered them when faced with a difficult problem
- I use the intentions to guide my way to knowing what to do
- It narrows down what I need to do and makes it more clear what the teacher is looking for.

What might help you in your learning?

- more examples
- It would help me to get students to explain to each other problems on the board; because teaching others always helps me deeper understand the subject.
- If the lessons were taught in the order of the learning intentions beginning with intention 1 and going to the last intention.
- More practice and real life application.
- Having a review of what I should know was very helpful.
- Repeated practice of problems so I can become used to working the problems with speed and correctness.
- Visual examples
- If practice problems were listed with each of the sections before the test
- More one-on-one teacher time to clear things I may be unsure about.
- Visual learning helps me
- Studying and practicing will improve my learning
- I think more interactive teaching could be used in order to help with my learning
- A designated review day to go back over any questions or confusion
- studying, practice problems
- More practice
- More practice
- Not having a job so I have more time to study.
- Stuff that helps me is just going through all questions the day we learn the unit and then I have it from there.
- I would say more "lecture" would help. Spending more time hearing the teacher explain would help me.

- more practice problems/ a practice open ended question
- Having a better attention span.
- I think that more abstract reasoning and drawing conclusions myself would help me in my learning.
- Having the learning intentions on the test helps but would help more if when learning we split each intention up to a lesson.
- More practice problems by hand without the use of a laptop.
- If my teacher gave us less hand outs to figure out on our own and taught us more in depth
- I do not know of anything that will help me. I did pretty well.
- It would be helpful to know how to improve my skills for each section after a quiz.
- Study more and realize what skill I'm not proficient at and learn more about it.
- some games would be intriguing
- more practice and explainations
- Studying what methods of problem solving correspond to each learning goal would help in my understanding of the material.
- Homework
- Maybe a tad bit more clarity through the unit.
- More group work
- Self learning or just doing practice problems.
- Being confident in my answers and try not to look for a second opinion
- I learn the best working practice problems and using worked examples, so as many practice problems as possible helps me be more confident.
- More practice of what is on the test and deeper understanding of what I am learning.
- Practice Tests
- Working math problems before taking the test
- I think what would help me in the long run would be more practice and one on one to see if how I feel about the questions.
- Getting a visual representation of things helps me understand where all of the factors are coming from rather than just being told they exist.
- Individual assistance

APPENDIX M

Interview Questions for Teacher

- What do you think about the impact of students rating and predicting their progress on learning targets before a test?
- What do you think about the impact of leveled learning progressions with worked examples on student learning?
- What do you think about the impact of emphasizing metacognition with students on student learning?
- What plans do you have, if any, for continuing any of what you have done this quarter
    - Next year?
    - For other units?
    - In other classes?
- What would you tell and/or recommend to other teachers about your experience this quarter?

APPENDIX N

Precalculus Learning Targets by Unit

Test 1 – Unit 7 Transformations of Parent Functions

7_1 I can graph and write the equation of a transformed parent function.

7_2 I can recognize transformations given a graph or equation.

7_3 I can determine properties of a graph of function such as domain, range, extrema, increasing, decreasing, constant, intercepts, and symmetry.

7_4 I can write a function or graph with given properties or determine that such a function cannot exist and why.

Test 2 – Unit 8 Piecewise, Inverse, and Composite Functions

8_1 I can graph, write equations for, and determine properties of piecewise functions.

8_2 I can determine if a function is continuous. I can identify discontinuities as removable (point) or nonremovable (jump or asymptotic).

8_3 I can rewrite absolute value functions as piecewise functions.

8_4 I can perform various operations on of functions, including addition, subtraction, multiplication, division, and composition.

8_5 I can determine properties of composite and inverse functions such as domain, range, and function values.

8_6 I can simplify the difference quotient of a polynomial, rational, or radical function.

Test 3 – Unit 9 Polynomial Functions

9_1 I can determine the roots (with multiplicity), extrema, end behavior, intercepts, concavity, and degree of a polynomial given a graph and/or equation.

9_2 I can determine whether a function is even, odd, or neither. I can determine the symmetry of a function.

9_3 I can write the equation of a polynomial given various properties such as roots, end behavior, intercepts, and degree.

9_4 I can sketch the graph of a polynomial given various properties such as roots, end behavior, intercepts, and degree.

9_5 I can find roots and factors of a polynomial using long and/or synthetic division.

9_6 I can solve polynomial inequalities.

APPENDIX O

Addendum: Unit 3_1 Pre-test Questions

Learning Goal Quiz – Please start with level three for each learning goal. Then use the Google form to determine which question to do next. Work independently. If you do not know the answer, please don't guess. Choose E for "I don't know how to do this problem."
NO CALCULATOR!!!!

LG1: I can use the derivative to determine maxima and minima of a function.
Level 3: Proficient
LG1_3) Find the absolute extrema of f on the given interval.
$f(x) = \frac{x}{x^2+1}, [0,2]$

A. Minimum at (0,0) & Maximum at (2, 2/5)

B. Minimum at (0,0) & Maximum at (1, 1/2)

C. Minimum at (-1, -1/2) & Maximum at (1, 1/2)

D. Minimum at (2,-3/25) & Maximum at (0,1)

E. I don't know how to do this problem.

Level 2: Progressing
LG1_2) Find the relative minimum of f. Justify your answer.
$f(x) = x^3 + 3x^2 - 9x + 7$

A. (-3, 34) because f' changes from + to -.

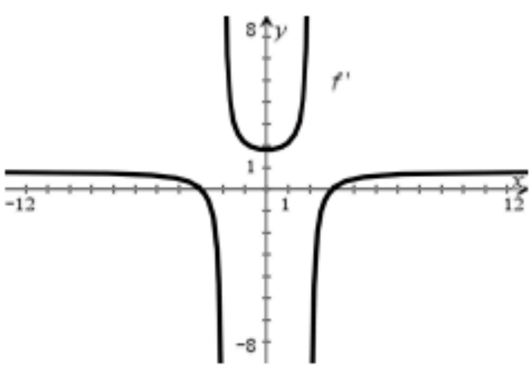
B. (1,0) because f' changes from + to -.

C. (1,2) because f' changes from - to +

D. (-3,0) because f' changes from - to +

E. I don't know how to do this problem.

Level 4: Exceptional
LG1_4) Given the graph of f' below, suppose f is continuous on the same intervals f' is continuous. Determine the location of the relative minimum of f.



A) x = -3

B) x = 3

C) x = 0

D) x = -2

E) I don't know how to do this problem.

LG2: I can use the Intermediate Value Theorem, the Extreme Value Theorem, and the Mean Value Theorem.

Level 3: Proficient

LG2_3) Determine whether the MVT can be applied to *f* on the given interval. If yes, find the value of c guaranteed by the MVT.

$f(x) = \frac{1}{x^2-1}$, [-3,3]

A) c = 0 B) c = ± 1 C) c = ± 3 D) MVT does not apply

E) I don't know how to do this problem.

Level 2: Progressing

LG2_2) Verify that Rolle's Theorem applies, then find the value(s) of c guaranteed by Rolle's Theorem for $f(x) = 2\cos(2x)$ on $\left[\frac{\pi}{2}, \frac{3\pi}{2}\right]$.

A) $c = \frac{3\pi}{4}$ B) $c = \frac{\pi}{2}, \frac{3\pi}{2}$ C) $c = \pi$ D) Rolle's Theorem does not apply.

E) I don't know how to do this problem.

Level 4: Exceptional

LG2_4) Suppose f is differentiable on [-2,3]. On which of the following interval(s) does Rolle's Theorem apply?

I. [0,2] II. [-2,0] III. [1,3]

x	-2	-1	0	1	2	3
f(x)	5	-2	3	0	3	0
f'(x)	-5	0	5	-2	2	1

A) I only B) II only C) I & II only D) I & III only

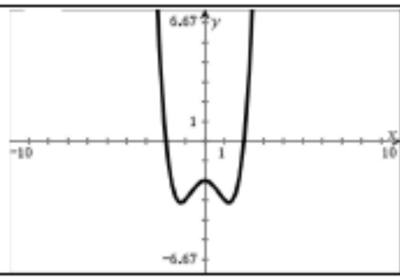
E) I don't know how to do this problem.

LG3) I can analyze functions from graphs, tables, and equations using different techniques.

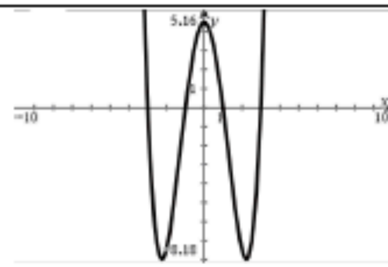
Level 3: Proficient

LG3_3) Which of the following could be the graph of $f(x) = \frac{1}{2}x^4 - \frac{3}{2}x^2 - 2$?

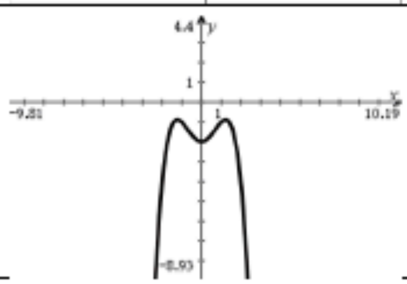
A.



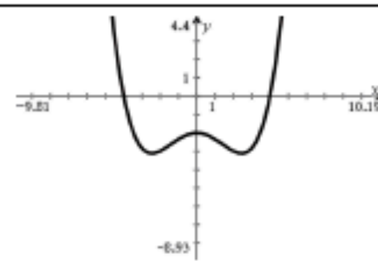
B.



C.



D.



E. I don't know how to do this problem.

Level 2: Progressing

LG3_2) Given the following information about f(x), on which of the following interval(s) could f(x) be concave up. Justify your answer.

x	(-5,-2)	x=-2	(-2,2)	x=2	(2,4)
f'(x)	positive	positive	positive	DNE	negative
f''(x)	negative	zero	positive	DNE	positive

A. (-2,2) U (2,4) because f''>0

B. (-5,2) because f'>0

C. (-2,4) because f' changes sign

D. (-5,-2) because f''<0

E. I don't know how to do this problem.

Level 4: Exceptional

LG3_4) Given the following information about a continuous function f(x), where does f(x) reach its absolute maximum? Justify your answer.

x	(-5,-2)	x=-2	(-2,2)	x=2	(2,4)
f'(x)	positive	positive	positive	DNE	negative
f''(x)	negative	zero	positive	DNE	positive

A. x = -2 because f''(-2) = 0.

B. x = 2 because f'(2) DNE.

C. x = 2 because f(x) increases until 2, then decreases after 2.

D. The absolute maximum cannot be determined.   E. I don't know how to do this problem.

LG4) I can use the original function to deduce information about the first and second derivatives.

Level 3: Proficient

LG4_3) Given $f(x) = \frac{1}{2x+3}$, find the interval on which f' is decreasing.

A. $\left(-\infty, -\frac{3}{2}\right) \cup \left(-\frac{3}{2}, \infty\right)$ because f'<0.

B. $(-\infty, \infty)$ because f'<0.

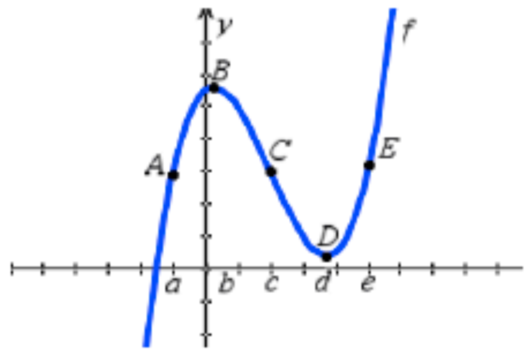
C. f(x) is always increasing because f'>0 for all x.

D. $\left(-\infty, -\frac{3}{2}\right)$ because f'<0.

E. I don't know how to do this problem.

Level 2: Progressing

LG4_2) Given the graph of *f* at the right, find the intervals on which *f'(x)* is negative and *f''(x)* is positive.



A. (d, e)

B. (b, c)

C. (b, d)

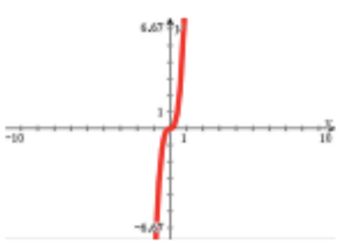
D. (c, d)

E. I don't know how to do this problem.

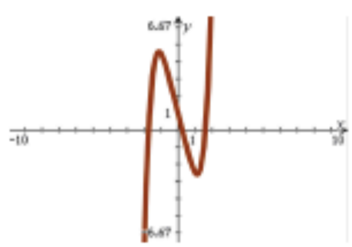
Level 4: Exceptional

LG4_4) Label the following graphs as either *f, f',* or *f''*.

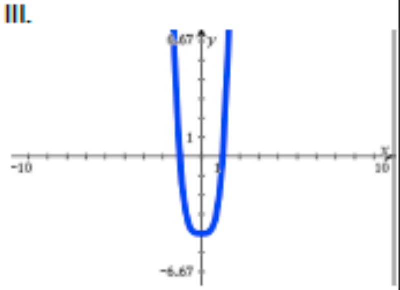
I.



II.



III.



A. f = I, f' = II, f'' = III

B. f = I, f' = III, f'' = II

C. f = II, f' = III, f'' = I

D. f = III, f' = II, f'' = I

E. I don't know how to do this problem.

LG5) I can use the derivative to deduce information about the second derivative and the original function.

Level 3: Proficient

LG5_3) Given $f'(x) = \sqrt{x+2}$, on what interval is f concave up? Justify your answer.

A. $(-2, \infty)$ because f'>0

B. $(-2, \infty)$ because f' is increasing

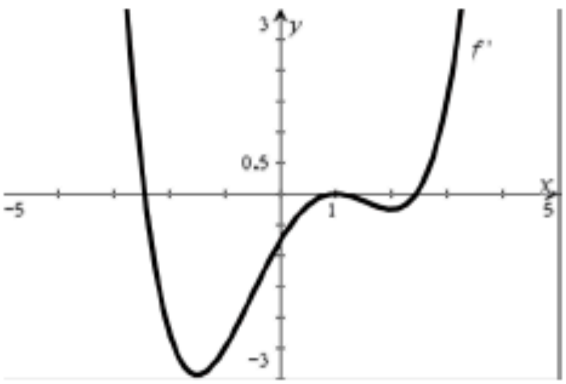
C. $(-\infty, -2)$ because f'<0

D. f is never concave up because f''<0 for all x in the domain

E. I don't know how to do this problem.

Level 2: Progressing

LG5_2) Given the graph of f' below, on what interval(s) is f decreasing? Justify your answer.



A. $(-\infty, -1.5) \cup (1,2)$ because f'<0

B. (-1, 1.5) because f''<0

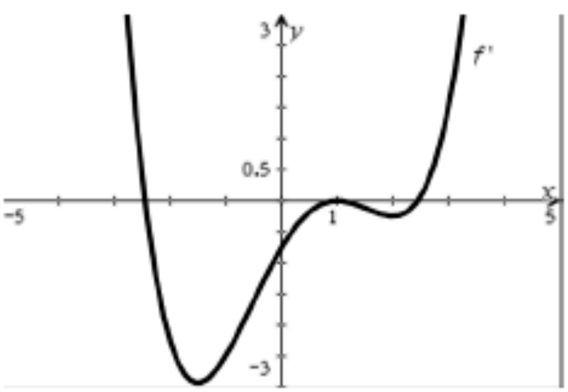
C. (-2.5, 2.5) because f'<0

D. (-1, 1.5) because f'<0

E. I don't know how to do this problem.

Level 4: Exceptional

LG5_4) Given the graph of f' below, on what interval(s) is f concave down? Justify your answer.



A. $(-\infty, -1.5) \cup (1,2)$ because f' is decreasing

B. (-1, 1.5) because f''<0

C. (-2.5, 2.5) because f'<0

D. (-1, 1.5) because f'<0

E. I don't know how to do this problem.

LG6) I can use the second derivative to deduce information about the first derivative and the original function.

Level 3: Proficient

LG6_3) Use the 2nd Derivative Test to determine the location of the relative minimum for the function $f(x) = \frac{1}{3}x^3 - 3x^2 + 8x + 5$. Justify your answer.

A. x = 3 because f'' changes sign

B. x = 3 because f''(3)=0

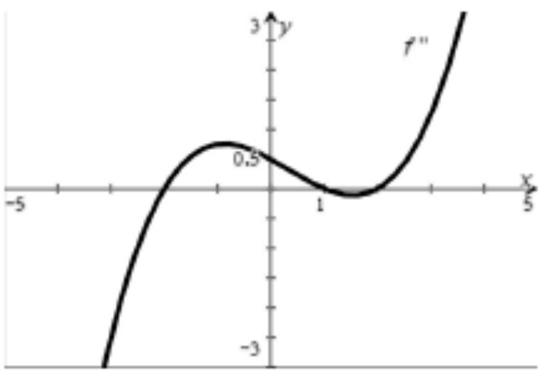
C. x = 2 because f''(2)<0

D. x = 4 because f''(4)>0

E. I don't know how to do this problem.

Level 2: Progressing

LG6_2) Given the graph of *f''*, determine where f is concave up. Justify your answer.



A. $(-2, 1) \cup (2, \infty)$ because f''>0

B. $(0.5, \infty)$ because f''>0

C. $(-\infty, -1) \cup (1.5, \infty)$ because f''>0

D. $(-\infty, -1) \cup (1.5, \infty)$ because f'' is increasing

E. I don't know how to do this problem.

Level 4: Exceptional

LG6_4) Which of the following functions has a point of inflection at x = a?

A. $f(x) = (x-a)^4$

B. $f(x) = (x-a)^5$

C. $f(x) = \frac{1}{(x-a)^5}$

D. $f(x) = \frac{1}{(x-a)^4}$

E. I don't know how to do this problem.

APPENDIX P

Addendum: Unit 3_1 Pre-test Form

Level Quiz Unit 3_1

Treat this like a quiz. I want to know what YOU know WITHOUT help.

* Required

1. **Student Number** *

____

Skip to question 3.

LG1: I can use the derivative to determine maxima and minima of a function.

2. **LG1_2**

Mark only one oval.

- ( ) A
- ( ) B
- ( ) C
- ( ) D
- ( ) I don't know how to do this problem.

Skip to question 6.

LG1: I can use the derivative to determine maxima and minima of a function.

3. **LG1_3**

Mark only one oval.

- ( ) A *Skip to question 2.*
- ( ) B *Skip to question 4.*
- ( ) C *Skip to question 2.*
- ( ) D *Skip to question 2.*
- ( ) I don't know how to do this problem. *Skip to question 2.*

LG1: I can use the derivative to determine maxima and minima of a function.

4. **LG1_4**

Mark only one oval.

- ( ) A
- ( ) B
- ( ) C
- ( ) D
- ( ) I don't know how to do this problem.

Skip to question 6.

LG2: I can use the Intermediate Value Theorem, the Extreme Value Theorem, and the Mean Value Theorem.

5. **LG2_2**

Mark only one oval.

- A
- B
- C
- D
- I don't know how to do this problem.

Skip to question 9.

LG2: I can use the Intermediate Value Theorem, the Extreme Value Theorem, and the Mean Value Theorem.

6. **LG2_3**

Mark only one oval.

- A *Skip to question 5.*
- B *Skip to question 5.*
- C *Skip to question 5.*
- D *Skip to question 7.*
- I don't know how to do this problem. *Skip to question 5.*

LG2: I can use the Intermediate Value Theorem, the Extreme Value Theorem, and the Mean Value Theorem.

7. **LG2_4**

Mark only one oval.

- A
- B
- C
- D
- I don't know how to do this problem.

Skip to question 9.

LG3) I can analyze functions from graphs, tables, and equations using different techniques.

8. **LG3_2**

Mark only one oval.

- A
- B
- C
- D
- I don't know how to do this problem.

Skip to question 12.

LG3) I can analyze functions from graphs, tables, and equations using different techniques.

9. LG3_3

Mark only one oval.

- ( ) A *Skip to question 10.*
- ( ) B *Skip to question 8.*
- ( ) C *Skip to question 8.*
- ( ) D *Skip to question 8.*
- ( ) I don't know how to do this problem. *Skip to question 8.*

LG3) I can analyze functions from graphs, tables, and equations using different techniques.

10. LG3_4

Mark only one oval.

- ( ) A
- ( ) B
- ( ) C
- ( ) D
- ( ) I don't know how to do this problem.

Skip to question 12.

LG4) I can use the original function to deduce information about the first and second derivatives.

11. LG4_2

Mark only one oval.

- ( ) A
- ( ) B
- ( ) C
- ( ) D
- ( ) I don't know how to do this problem.

Skip to question 15.

LG4) I can use the original function to deduce information about the first and second derivatives.

12. LG4_3

Mark only one oval.

- ( ) A *Skip to question 13.*
- ( ) B *Skip to question 11.*
- ( ) C *Skip to question 11.*
- ( ) D *Skip to question 11.*
- ( ) I don't know how to do this problem. *Skip to question 11.*

LG4) I can use the original function to deduce information about the first and second derivatives.

13. **LG4_4)**

Mark only one oval.

- ( ) A
- ( ) B
- ( ) C
- ( ) D
- ( ) I don't know how to do this problem.

Skip to question 15.

LG5) I can use the derivative to deduce information about the second derivative and the original function.

14. **LG5_2)**

Mark only one oval.

- ( ) A
- ( ) B
- ( ) C
- ( ) D
- ( ) I don't know how to do this problem.

Skip to question 18.

LG5) I can use the derivative to deduce information about the second derivative and the original function.

15. **LG5_3)**

Mark only one oval.

- ( ) A *Skip to question 14.*
- ( ) B *Skip to question 16.*
- ( ) C *Skip to question 14.*
- ( ) D *Skip to question 14.*
- ( ) I don't know how to do this. *Skip to question 14.*

LG5) I can use the derivative to deduce information about the second derivative and the original function.

16. LG5_4)

Mark only one oval.

- A
- B
- C
- D
- I don't know how to do this problem.

Skip to question 18.

LG6) I can use the second derivative to deduce information about the first derivative and the original function.

17. LG6_2)

Mark only one oval.

- A
- B
- C
- D
- I don't know how to do this problem.

Stop filling out this form.

LG6) I can use the second derivative to deduce information about the first derivative and the original function.

18. LG6_3)

Mark only one oval.

- A *Skip to question 17.*
- B *Skip to question 17.*
- C *Skip to question 17.*
- D *Skip to question 19.*
- I don't know how to do this problem. *Skip to question 17.*

LG6) I can use the second derivative to deduce information about the first derivative and the original function.

19. LG6_4)

Mark only one oval.

- A
- B
- C
- D
- I don't know how to do this problem.

APPENDIX Q

Addendum: Unit 3_1 Learning Goals Self-Assessment Form

Information

You do not have to participate in this survey. If you choose to participate, you do not have to answer any question that you would rather not answer, and you can exit the survey at any time.

1. **Student Number (the researcher will not be able to identify you by name throughout the study)**

   ____

I can use the derivative to determine maxima and minima of a function.

1: Beginning
2: Progressing
3: Proficient
4: Exceptional

2. **On test day, I predict I will be at level**
   Mark only one oval.

1	2	3	4
⬭	⬭	⬭	⬭

I can use the Intermediate Value Theorem, the Extreme Value Theorem, and the Mean Value Theorem.

1: Beginning
2: Progressing
3: Proficient
4: Exceptional

3. **On test day, I predict I will be at level**
   Mark only one oval.

1	2	3	4
⬭	⬭	⬭	⬭

I can analyze functions from graphs, tables, and equations using different techniques.

1: Beginning
2: Progressing
3: Proficient
4: Exceptional

4. **On test day, I predict I will be at level**
   Mark only one oval.

1	2	3	4
⬭	⬭	⬭	⬭

I can use the original function to deduce information about the first and second derivatives.

1: Beginning
2: Progressing
3: Proficient
4: Exceptional

5. **On test day, I predict I will be at level**

   Mark only one oval.

1	2	3	4
⬭	⬭	⬭	⬭

I can use the derivative to deduce information about the second derivative and the original function.

1: Beginning
2: Progressing
3: Proficient
4: Exceptional

6. **On test day, I predict I will be at level**

   Mark only one oval.

1	2	3	4
⬭	⬭	⬭	⬭

I can use the second derivative to deduce information about the first derivative and the original function.

1: Beginning
2: Progressing
3: Proficient
4: Exceptional

7. **On test day, I predict I will be at level**

   Mark only one oval.

1	2	3	4
⬭	⬭	⬭	⬭

Next Steps

8. **What do you plan to do to reach your predicted learning levels? (realistically, select all that apply)**

   Check all that apply.

- [ ] Use the worked examples my teacher provided
- [ ] Study with another student
- [ ] Get help from a teacher or tutor
- [ ] Watch calculus videos
- [ ] Review class notes
- [ ] Other: ____________________

APPENDIX R

Addendum: Learning Goals Reflection Form

Information

You do not have to participate in this survey. If you choose to participate, you do not have to answer any question that you would rather not answer, and you can exit the survey at any time.

1. **Student Number (the researcher will not be able to identify you by name throughout the study)**

____

Actions

2. **What did you do to reach your predicted learning levels? (select all that apply)**
Check all that apply.

- [ ] Use the worked examples my teacher provided
- [ ] Study with another student
- [ ] Get help from a teacher or tutor
- [ ] Watch calculus videos
- [ ] Review class notes
- [ ] Other: ______________________________

3. **Did what you do helped? Explain.**

____
____
____
____
____

4. **What might you do next time instead of or in addition to what you did this time?**

____
____
____
____
____

APPENDIX S

Addendum: AP Calculus Learning Targets by Unit

Test 1 – Unit 2 Derivatives

2-1 I can use the definition of the derivative.

2-2 I can evaluate derivatives from graphs, tables, and equations using different techniques.

2-3 I can write the equations of tangent and normal lines at a point on a graph.

2-4 I can solve related rates problems with a real-world context.

Test 2 – Unit 3_1 Applications of Differentiation

3_1-1 I can use the derivative to determine maxima and minima of a function.

3_1-2 I can use the Intermediate Value Theorem, the Extreme Value Theorem, and the Mean Value Theorem.

3_1-3 I can analyze functions from graphs, tables, and equations using different techniques.

3_1-4 I can use the original function to deduce information about the first and second derivatives.

3_1-5 I can use the derivative to deduce information about the second derivative and the original function.

3_1-6 I can use the second derivative to deduce information about the first derivative and the original function.

Test 3 – Unit 3_2 Applications of Differentiation

3_2-1 I can use the tangent line at a point to approximate values of the function near the point of tangency.

3_2-2 I can use L'Hopital's Rule to evaluate a limit.

3_2-3 I can determine the differential for a function.

3_2-4 I can solve optimization problems with a real-world context.

3_2-5 I can solve related rates problems with a real-world context.

Test 4 – Unit 4 Antidifferentiation

4-1 I can approximate the area under a curve using Riemann Sums.

4-2 I can approximate the area under a curve using the Trapezoidal Rule.

4-3 I can set up and calculate the exact area under a curve using the limit of the sum of the areas of an infinite number of rectangles.

4-4a I can use the Fundamental Theorem of Calculus.

4-4b I can use the Second Fundamental Theorem of Calculus.

4-5 I can antidifferentiate using various techniques, including substitution of variables.

Test 5 – Unit 5 Transcendental Functions

5-1a I can calculate and use derivatives of exponential functions.

5-1b I can calculate and use derivatives of logarithmic functions.

5-2 I can calculate and use antiderivatives of exponential functions.

5-3 I can calculate and use antiderivatives involving logarithmic functions.

5-4 I can calculate and use slopes for inverse functions.

5-5 I can calculate and use derivatives of inverse trigonometric functions.

5-6 I can calculate and use antiderivatives involving inverse trigonometric functions.

APPENDIX T

Addendum: Learning Goals Reflection Responses

Test 1 – Unit 2

What did you do to reach your predicted learning levels? (select all that apply)	Did what you do helped? Explain.	What might you do next time instead of or in addition to what you did this time?
Watch calculus videos	I believe it did	Study longer
Use the worked examples my teacher provided, Watch calculus videos, Review class notes	I think it did help me do my better than i would have without it. I didn't do great on the test, but I think reviewing everything definitely helped me grasp the concepts better.	I would review like I did but I wish I would have gone back over definition of derivative problems because I struggled with those.
Use the worked examples my teacher provided, Study with another student, Watch calculus videos, Review class notes	No. I still failed miserably	Get a tutor
Use the worked examples my teacher provided, Watch calculus videos, Review class notes	Yes, I improved on my learning levels.	I should get tutored.
Absolutely nothing	Sure did help me stay at level 1	Actually study for the tests
Use the worked examples my teacher provided	Yes it did because it help me remember what I needed to do.	Review and study with others.
Use the worked examples my teacher provided, Get help from a teacher or tutor, Watch calculus videos, Review class notes	I felt like what I did, didn't really help me. I was learning the basics and testing the waters of unit 2. I was able to find the answers to unit 2 questions if they were given to me at face value. On the test, I felt like I had to incorporate a lot of rules and formulas just to find an answer. Doing that confuses me a lot and I think I may have done bad on the test because of that. When we did test corrections, I was able to see what I did wrong	Next time, if something is not clear to me, I will get help immediately. I wont sit around and let the class get ahead of me.
Use the worked examples my teacher provided, Study with another student, Watch calculus videos	Yes because I was less confident on the objectives until I practiced the weekend	To do mathxl a week earlier
Use the worked examples my teacher provided, Get help from a teacher or tutor	It helped for some of the learning goals but I should have prepared more for LG1 and LG3	
Study with another student, Watch calculus videos	It gave me a broad understanding but I still didn't know how to do everything.	Study more
Use the worked examples my teacher provided, Watch calculus videos	I thought what I did helped but once I got to the test I realized my knowledge was not enough	maybe study with friends
Study with another student, Watch calculus videos, Review class notes	Obviously not, because I still got a bad grade.	Literally everything because I need it apparently.

Study with another student	Yes. Going over problems with another student helped me see their strategy at solving the problem.	I will watch the calculus videos and get help from a teacher or tutor.
Use the worked examples my teacher provided, Watch calculus videos	Extremely	Review notes too
Use the worked examples my teacher provided, Watch calculus videos, Review class notes	It helped a little. It probably would have helped more if I did more of it.	I will probably get help from a teacher during zero block when I have time.
Review class notes	Kind of, i got to review what we already went over	So much more, review videos, practice
I did various practice problems, namely the FRQs	Yes, by doing all seven of the FRQs, I was more than prepared for the test	Next time I will more than likely work the self assessments that's available in addition to the FRQs
Review class notes	It was enough, so I was not prepared	Everything
Use the worked examples my teacher provided, Watch calculus videos, Review class notes	some of the videos did gelp	Maybe getting more teacher help
Use the worked examples my teacher provided, Get help from a teacher or tutor, Watch calculus videos	Yes, I felt much more prepared for the test than I did on pre-assessment day.	Next time, I will try to work more challenging questions to ensure that I can reach the answer with accurate (aka not forgetting a step/making a mathematical error)
Watch calculus videos, Review class notes	It did some, but not much.	Look at worked examples of the problems and get help from a tutor
Study with another student, Watch calculus videos	I was under the impression I knew the material.	I will do more of what I did to study for this test but use more materials and different questions.
Review class notes	Yes, because there were several concepts that could only be learned through rote memorization.	I might also work some problems on Canvas.
Watch calculus videos	No. I needed a better understanding that a video could not help with.	Ask teachers or other students with a better understanding about the material.
Use the worked examples my teacher provided, Watch calculus videos	Yes	Study with another student
Use the worked examples my teacher provided, Review class notes	Kind of, I feel like I could have tried harder to prepare myself but got swamped with work from other classes.	I would prepare earlier.
Use the worked examples my teacher provided, Study with another student	I think it did because I did pretty good on some sections of the test that I actually studied hard for.	I could practice and study the videos more.

Test 2 – Unit 3_1

What did you do to reach your predicted learning levels? (select all that apply)	Did what you do helped? Explain.	What might you do next time instead of or in addition to what you did this time?
Review class notes	Yes	Actually study
Use the worked examples my teacher provided, Watch calculus videos	Yes, the videos explained the subjects I did not know.	I will do edpuzzles.
Use the worked examples my teacher provided, Watch calculus videos, Review class notes, sibling help	Called my brother to explain everything I didn't understand	study more than the night before the test
Study with another student	Kind of? If I didn't do anything I would've failed harder than if I did	Hopefully I'll actually study more
Use the worked examples my teacher provided, Get help from a teacher or tutor, Review class notes	Yes, I understood the major concepts.	I should watch calculus videos.
Use the worked examples my teacher provided, Watch calculus videos, Review class notes	I thought it did but I did not do well on the test so I guess not.	Study more I guess
Use the worked examples my teacher provided, Review class notes	No, I did not study the notes as much as I needed	Study routinely
Watch calculus videos, Review class notes	I just understood the information in class better	Actually study. I say I'm going to study every time and I never do. I'm really trying to change that.
Use the worked examples my teacher provided, Review class notes, Learning Goal Quiz	Yes, it made me feel better about recognizing the types of questions and what was expected for the answers.	I might watch some videos to prepare more to make sure that I have everything down.
Use the worked examples my teacher provided, Watch calculus videos, Review class notes	Yes, my levels from the first quiz went up on the test.	Study with another student because they might know an easy way to do something.
Use the worked examples my teacher provided, Study with another student, Review class notes	I feel like looking at the problems that the teacher gave on canvas and through the level quiz helped.	I probably should watch more of the videos on Edpuzzle.
Use the worked examples my teacher provided, Study with another student, Review class notes	I got help from a student, and it helped to have someone else's explanation as well.	Watch the videos.
Use the worked examples my teacher provided, Watch calculus videos, Review class notes	It definitely helped to review the worked examples because they helped me to understand.	Next time, I will also study outside of school with some friends.
Use the worked examples my teacher provided, Study with another student, Review class notes	It was not enough , for the results were not high	More
Watch calculus videos, FRQs	It most definitely did help. The FRQs were similar to the questions on the test, so I feel like I had an edge, if you will, and it really helped me recognize similar questions.	Next time, I'd more than likely study with someone else other than trying to do it all by myself.
I worked a FRAPPY and a lab	Maybe? I did a lot better on the test than I did on the practice.	Nothing comes to mind

Watch calculus videos	Kind of, I didn't study too much.	Study more
Use the worked examples my teacher provided, Study with another student	Yes. Going over several practice problems and making sure I knew what each question was asking definitely helped.	More practice problems. Watch calculus videos.
Use the worked examples my teacher provided, Watch calculus videos	I think it was but I was tired so I didn't fully absorb the information	review with others
Use the worked examples my teacher provided, Study with another student	yes, I was able to work through the type of problems that were on the test	I will study more before the test, rather than just the block before
I ended up not doing anything :((		I am going to try to do what i said i will do.
Use the worked examples my teacher provided, Watch calculus videos	Kind of	Be able to do all of the canvas quizzes and watch more videos on fuzzy content and work more examples.
Use the worked examples my teacher provided, Watch calculus videos, Review class notes, The mighty Khan academy	It did indeed. I would not have gotten the curve without it	Get that kid named Lee to tutor me finally.

Test 3 – Unit 3_2

What did you do to reach your predicted learning levels? (select all that apply)	Did what you do helped? Explain.	What might you do next time instead of or in addition to what you did this time?
Study with another student, Watch calculus videos	Yes	Get help from the teacher
Watch calculus videos, Review class notes, MathXL	Honestly yes it helped so much.	I have definitely got to watch more edpuzzles because those things work wonders.
Use the worked examples my teacher provided, Study with another student, Review class notes	Studying with classmates really cleared up some confusion	Prepare much more and learn related rates
I asked classmates questions	Yes, i got things i was confused on kind of made clearer	The things i said i would do
Use the worked examples my teacher provided, Watch calculus videos, Review class notes	Yes. I did not understand L'Hopital's Rule or related rate problems before studying.	Maybe work more problems.
Use the worked examples my teacher provided, Study with another student, Review class notes	A little....as in .001 percent	make more time rather stress my mind out
Use the worked examples my teacher provided, Study with another student, Get help from a teacher or tutor	yes. The self assessment provided me challenging questions so I could solidify my knowledge on the LGs	I would like to do the canvas questions.
	No. I got a 50 on the test.	Lee said the FRQs are helpful, and rollover PSP is never a bad thing. I'll probably do most if not all of those.

Use the worked examples my teacher provided, Study with another student, Watch calculus videos	It did help a lot. Being able to study with a friend helped me understand where I was going wrong	Do mathxl and canvas practices as the unit progresses
Watch calculus videos, Review class notes	yes, I wouldn't have known how to do the limit problems	Steady all the terms on the test.

Test 4 – Unit 4

What did you do to reach your predicted learning levels? (select all that apply)	Did what you do helped? Explain.	What might you do next time instead of or in addition to what you did this time?
Use the worked examples my teacher provided, Study with another student, Get help from a teacher or tutor, Watch calculus videos, Review class notes	It helped for the most part. I just did not do enough.	I would take more time to study and do more activities.
Use the worked examples my teacher provided, Get help from a teacher or tutor, Watch calculus videos, Review class notes	Yes, it helped me know each skill that I needed for the test.	I would like to do the canvas quizzes
Study with another student, Review class notes	A little. I didn't try very hard.	If my exam grade was poor, I will work probably the whole review.
Use the worked examples my teacher provided, Review class notes		
Use the worked examples my teacher provided, Watch calculus videos, Review class notes	I thought it helped but my grade said it didn't. It was mostly the trig functions that tripped me up this time.	Probably look over more examples of finding the integrals of different trig functions.
Study with another student	Not for this particular test, but I plan to retake it when we get back to school.	Watch videos and find my notes for class
Use the worked examples my teacher provided, Watch calculus videos	I went on the student document and read through all the papers. I thought that helped me out a lot because during class, I was not able to grasp a complete understanding of the unit.	I might do more self assessments along with the videos and student folder.
Use the worked examples my teacher provided, Study with another student	It helped me understand my mistakes more	Exactly the same thing
Use the worked examples my teacher provided, Study with another student, Watch calculus videos	Some of it did, but I feel like I could have done a little more.	I will probably start working a little bit more ahead of time so that I have time to ask more questions that I can't figure out on my own or online.
Use the worked examples my teacher provided, Study with another student, Review class notes	It helped mostly. I didn't reach my goal but I did improve significantly with my understanding.	I might watch some videos and do a little more of what I did.

Use the worked examples my teacher provided, Study with another student, Review class notes	A little. I could have done better if I had more time, but I'm a slow test taker.	I might look at calculus videos.
Review class notes	It did, a little refresher	Study with someone else
Use the worked examples my teacher provided, Study with another student, Review class notes	Yes it did. I got a really good score on the test..	Watch some calculus videos
Use the worked examples my teacher provided, Watch calculus videos, Review class notes	Khan Academy really helped me learn the fundamental theorem of calculus in more detail than I was about to in class.	Do more FRQs!
FRQs	Yes doing the AP practice problems are extremely effective as they as the similar types of questions asked on the tests	Next time I'd probably study with a student or look at worked notes
Use the worked examples my teacher provided, Study with another student, Watch calculus videos, Review class notes	I think it did	More studding

Test 5 – Unit 5

What did you do to reach your predicted learning levels? (select all that apply)	Did what you do helped? Explain.	What might you do next time instead of or in addition to what you did this time?
Use the worked examples my teacher provided, Watch calculus videos, Review class notes	Nope- I had no idea what I was doing	Get help from a tutor
Use the worked examples my teacher provided	Kind of. I didn't do it to the extent that is necessary.	Study more
Made flash cards	No. I don't know why, but knowing more things didn't help.	??? MOAR FLASH CARDS
Use the worked examples my teacher provided, Review class notes	Decently until I forgot	Do it more
Mathxl :(	No, cant study with math xl	Study notes
Use the worked examples my teacher provided, Review class notes	I reviewed the notes in class, and I felt like that helped me understand a bit more.	I think I might review the notes in the student folder more.
Use the worked examples my teacher provided	No, I didn't have a good grasp on the subject to begin with, so the problems didn't help my understanding of this unit.	Watch khan academy
Use the worked examples my teacher provided, Review class notes	I worked some of the problems from class and worked the self assessment and the frqs	The procrastination stressed me out! But I think it made me work harder.
Use the worked examples my teacher provided, Study with another	Kind of	Watch more videos on how to do the topic.

student, Review class notes, Self assessment		
Review class notes		
Use the worked examples my teacher provided, Study with another student, Review class notes, MathXL	It did help me because on a good bit of problems I felt I knew where to start at least.	Do my homework on time
Use the worked examples my teacher provided, Watch calculus videos	Worked with friends outside of class	learn the material enough to pass the test.

VITA

Jennifer Carnes Wilson

Profile

My philosophy of teaching and learning mathematics can be summed up in the name of my blog, "Easing the Hurry Syndrome", and a few Twitter hashtags: #slowmath and #AskDontTell. I believe that all students can learn, and I seek to create a community of learners where questions are not only welcomed but sought through open-ended tasks and inquiry-based instruction. I have learned the most from the work of Dylan Wiliam (*Embedded Formative Assessment*), Mary Kay Stein and Margaret Schwan Smith (*5 Practices for Orchestrating Productive Mathematics Discussions*), and James Popham (*Transformative Assessment*, *Transformative Assessment in Action*). Their research on formative assessment and student discourse, coupled with implementing the Common Core Standards for Mathematical Practice, has transformed my classroom over the years. While my most recent work has shifted from young learners to adult learners, I continue to believe that all learners can learn, that learners don't come to the learning episode void of knowledge, and that questions and reflection are integral to a shared learning experience.

Education & Licensure

Ed.D. Education, emphasis secondary math, The University of Mississippi	expected May 2019
M.S. Mathematics, summa cum laude, Mississippi College	July 2003-2005
B.S. Mathematics, special distinction, Mississippi College	August 1990-May 1993
National Board for Professional Teaching Standards #219902258, AYA Math	November 1999-2029
State of Mississippi Educator License, Mathematics 7-12, AP Calculus BC	valid through June 2025

Experience

Illustrative Mathematics **April 2018-present (full-time), November 2013-March 2018 (contractor)**

- High School Professional Learning Lead, High School Content Writer, Illustrative Mathematics Master Coach/Facilitator for virtual and face-to-face trainings such as *Using Mathematical Routines for Purposeful Instruction*, *5 Practices*, and Illustrative Mathematics Algebra 1, Geometry, Algebra 2 Math Curriculum Unit Overviews, Writing Professional Development Modules for Illustrative Mathematics 6–8 Math Curriculum, Item & Task Review, Smarter Balanced Digital Library Project

Rankin County School District, Brandon, MS **Aug. 2003-Sept. 2017 (retired), Aug. 1996-May 2002**

- Curriculum Specialist – Mathematics (July 2013-September 2017): Work with K-12 teachers to implement standards, curriculum, Math Practices, formative assessment, teaching with technology; deliver professional learning; SREB/Mathematics Design Collaborative (MDC) Coach to assist teachers implementing Mathematics Assessment Project Formative Assessment Lessons

- Northwest Rankin High School Mathematics Department Chair, Leadership Team, & Teacher: Last taught AP Calculus and geometry; experience teaching all high school mathematics courses; leading mathematics Professional Learning Community

William Carey University, Hattiesburg, MS **July 2009-present**

- Currently teach online and have taught face-to-face graduate level courses incorporating mathematics teaching and the appropriate use of technology in the classroom

Additional Experience

- Clinton High School (10-12), Clinton Public Schools, August 2002-May 2003
- Byram Attendance Center (8-12), Hinds County Public Schools, August 1993-May 1996

Professional Service & Publications

- www.https://easingthehurrysyndrome.wordpress.com, Blog reflecting on lessons that I teach and instructional adjustments that I make throughout the lesson
- www.https://slowmathmovement.wordpress.com, Blog connecting the Slow Movement (food, music, exercise, money, travel, …) with mathematics education
- Texas Instruments Teachers Teaching with Technology Instructor Program, 2007-present
    - Professional Development Instructor and Author, Webinar Presenter, numerous speaking engagements including TI ASSM Dinner, April 2012 and 2015, TI NCSM Luncheon, April 2013, TI International Conferences, CMC-South, NCSM, NCTM, AP Annual Conference; Pilot Teacher
- Southern Region Educational Board (SREB) High Schools That Work (HSTW) Mathematics Design Collaborative (MDC) Certified Local Trainer
- College Board Pre-AP Mathematics Development Committee, AP Calculus Syllabus Project, Reader
- Mississippi Department of Education
    - CCRS Math Task Force; Geometry In stitute Author & Presenter; Summer Boot Camp Author & Presenter, 2014; Publication, Secondary Tech Discovery Curriculum Revision, April 2006
- Mississippi Council of Teachers of Mathematics
    - Treasurer, 2004-2012; NCTM Representative, 1995-2004; Conference presenter, 2005-2018
- Publication, case study for *Instructional Leadership in the Content Areas: Case Studies for Curriculum and Instruction* published by Routledge/UCEA (New York), 2018.
- Publication, "BackTalk: Easing the Hurry Syndrome", Phi Delta Kappan Magazine, May 2011
- Publication, CARS (Career Awareness: Roadway to Success), through MDOT & RCU for STEM, 2008

Awards

- Presidential Award for Excellence in Mathematics & Science Teaching, 2011
- T^3 Leadership Award, March 2014
- STAR Teacher, 2015, 2014, 2012, 2011, 2010, 2005
- Mississippi College Mathematics Alumnus Award, 2012
- 2010 Yale Educator Award
- Rankin County School District Teacher of the Year, 2008; NWRHS Teacher of the Year, 2008, 2006; Teacher of the Month, April 2005